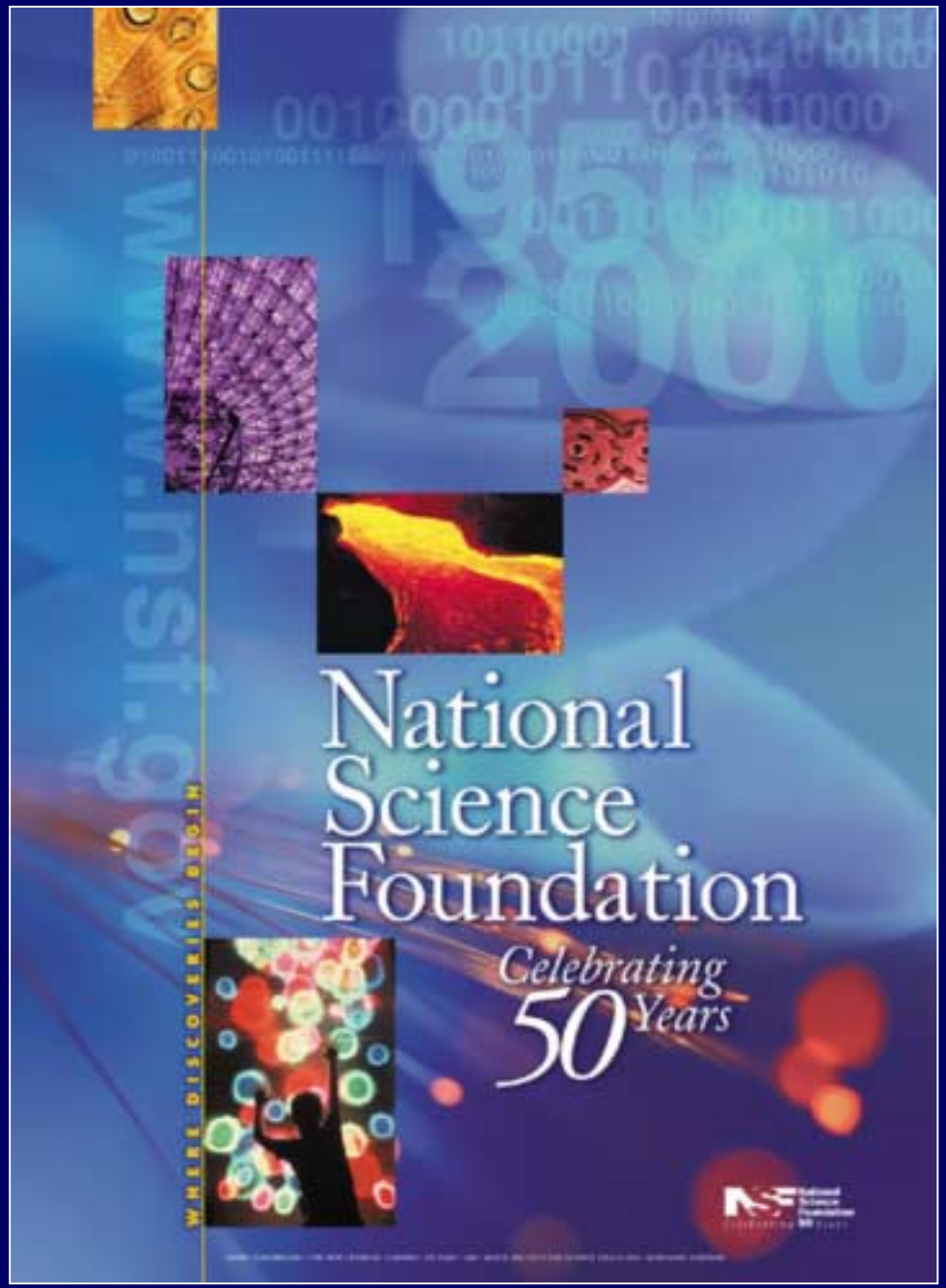
The Future of the Physical Sciences: A View from Washington

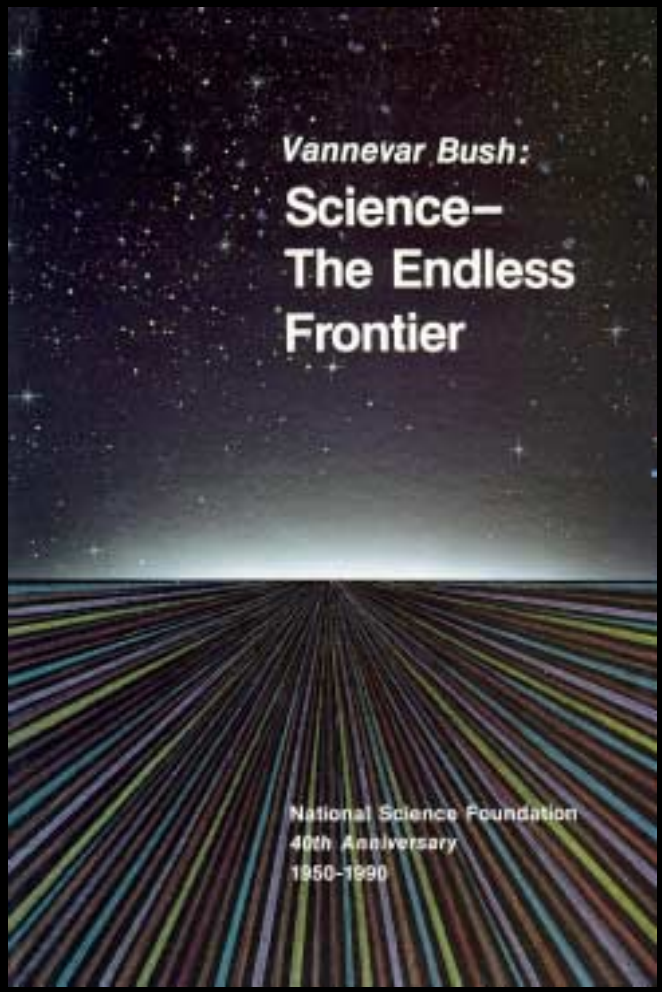
DESY Colloquium

April 15, 2003

Robert Eisenstein
CERN
US National Science Foundation

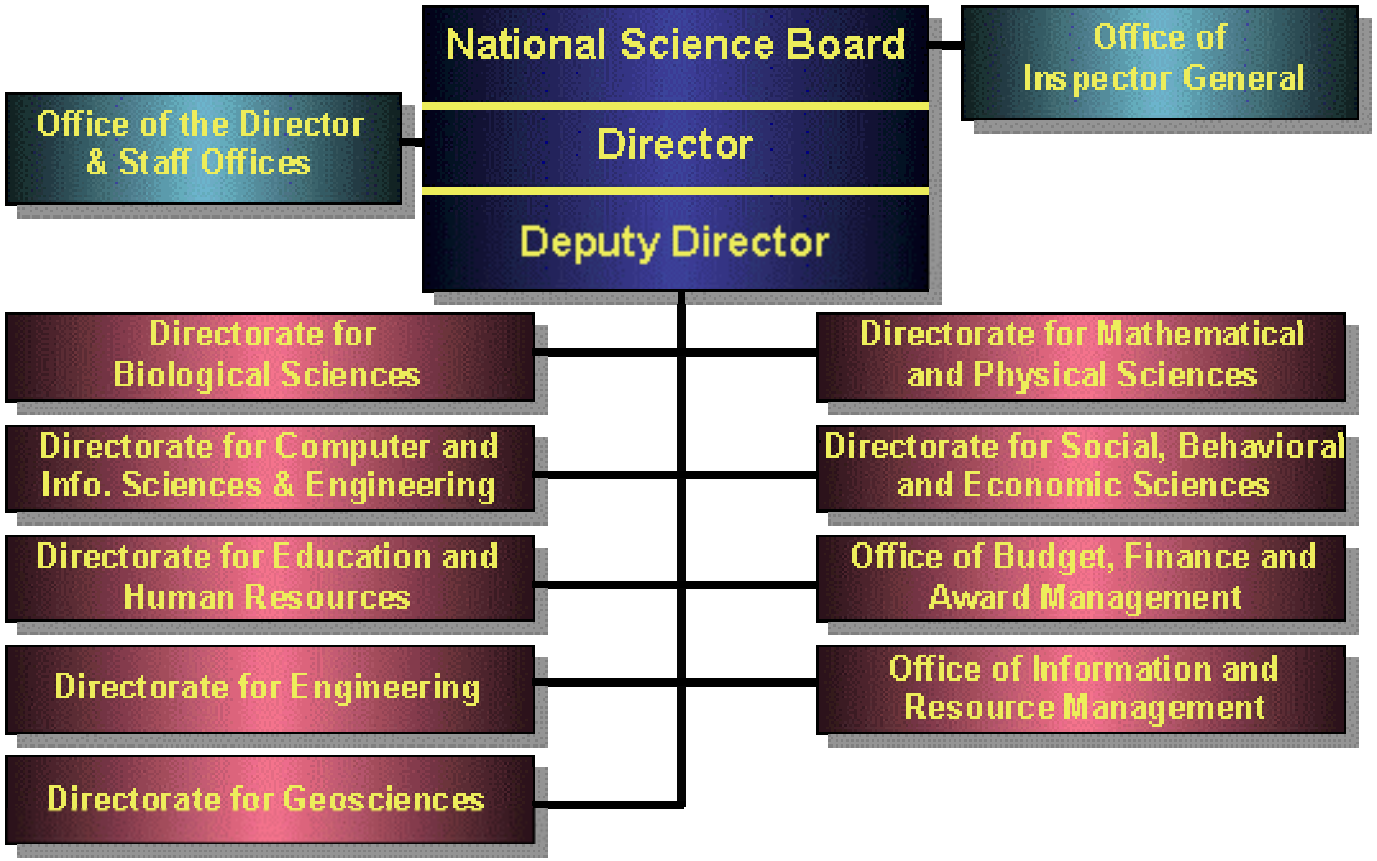

WHERE DISCOVERIES BEGIN
National Science Foundation
Celebrating 50 Years

Our Founder



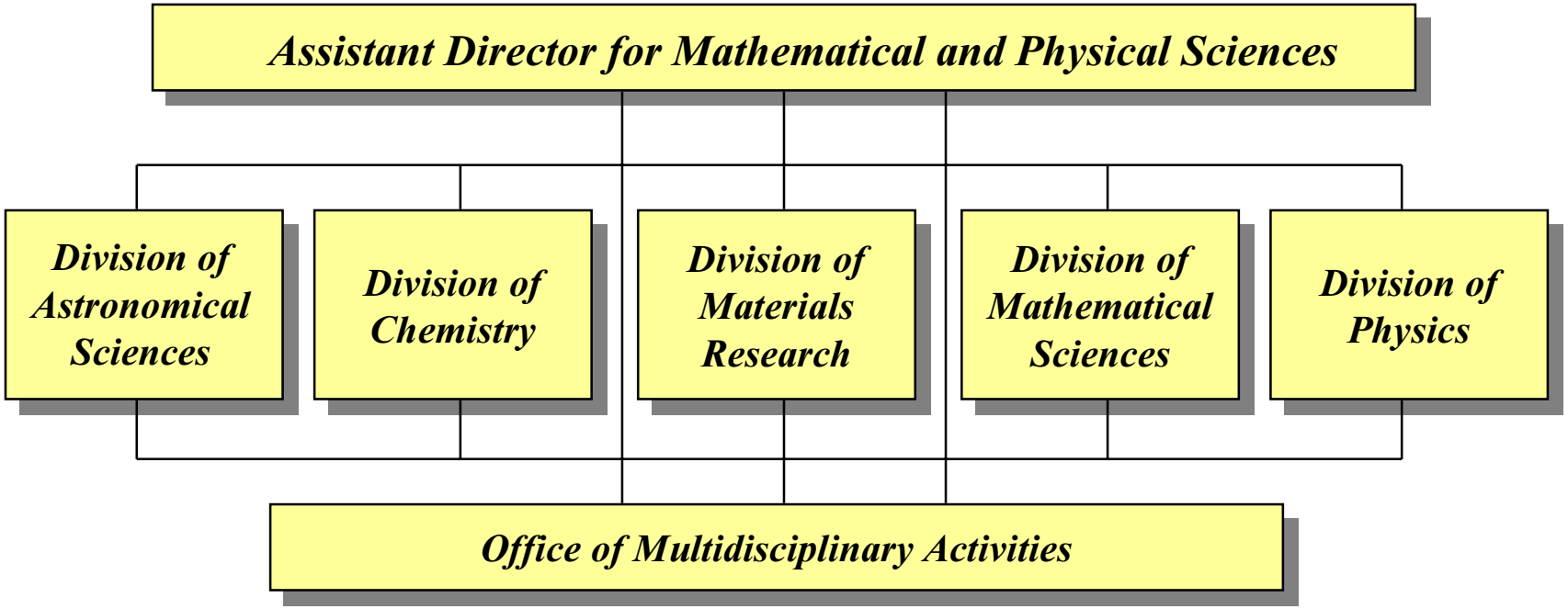
Vannevar Bush

National Science Foundation



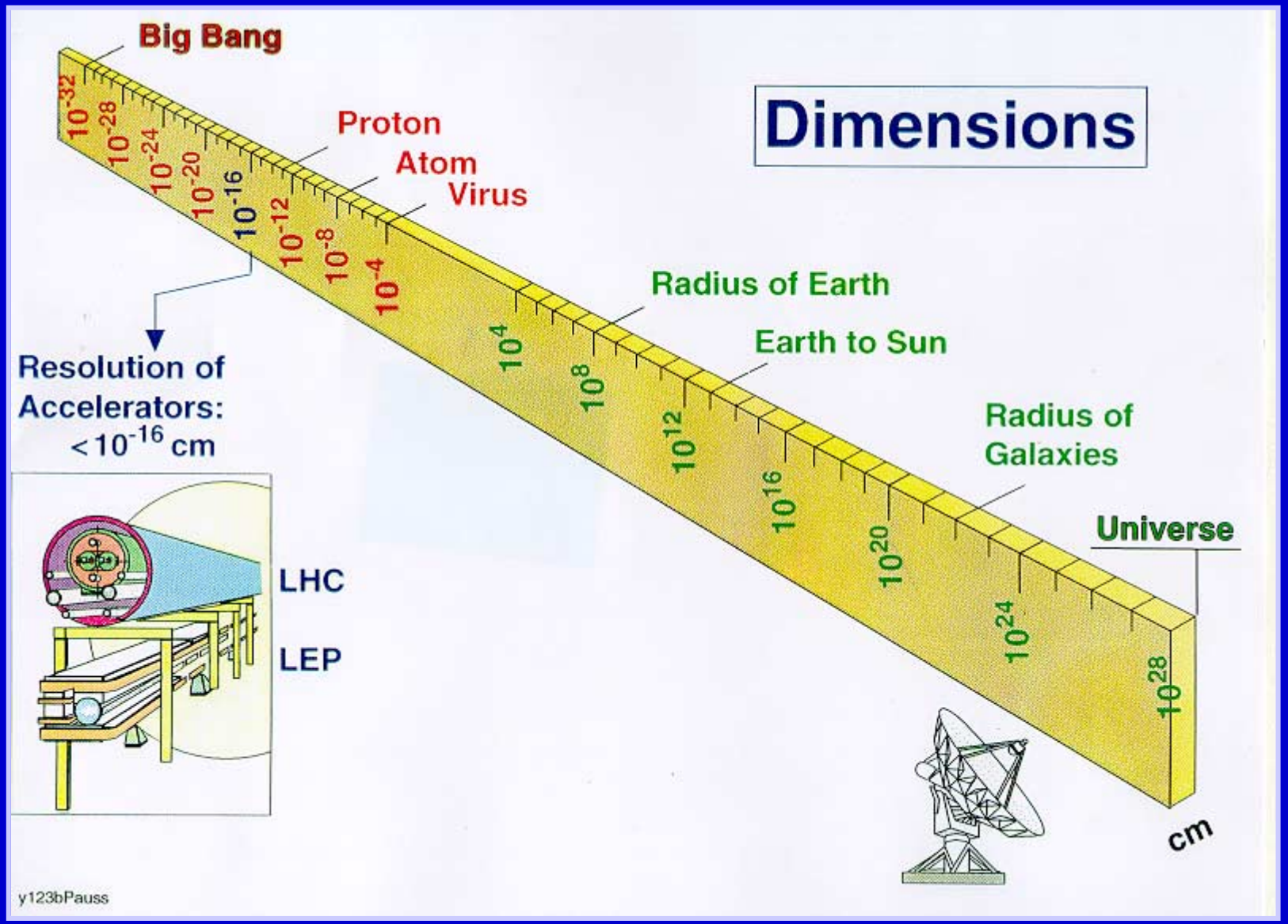
Ideas

Directorate for Mathematical and Physical Sciences

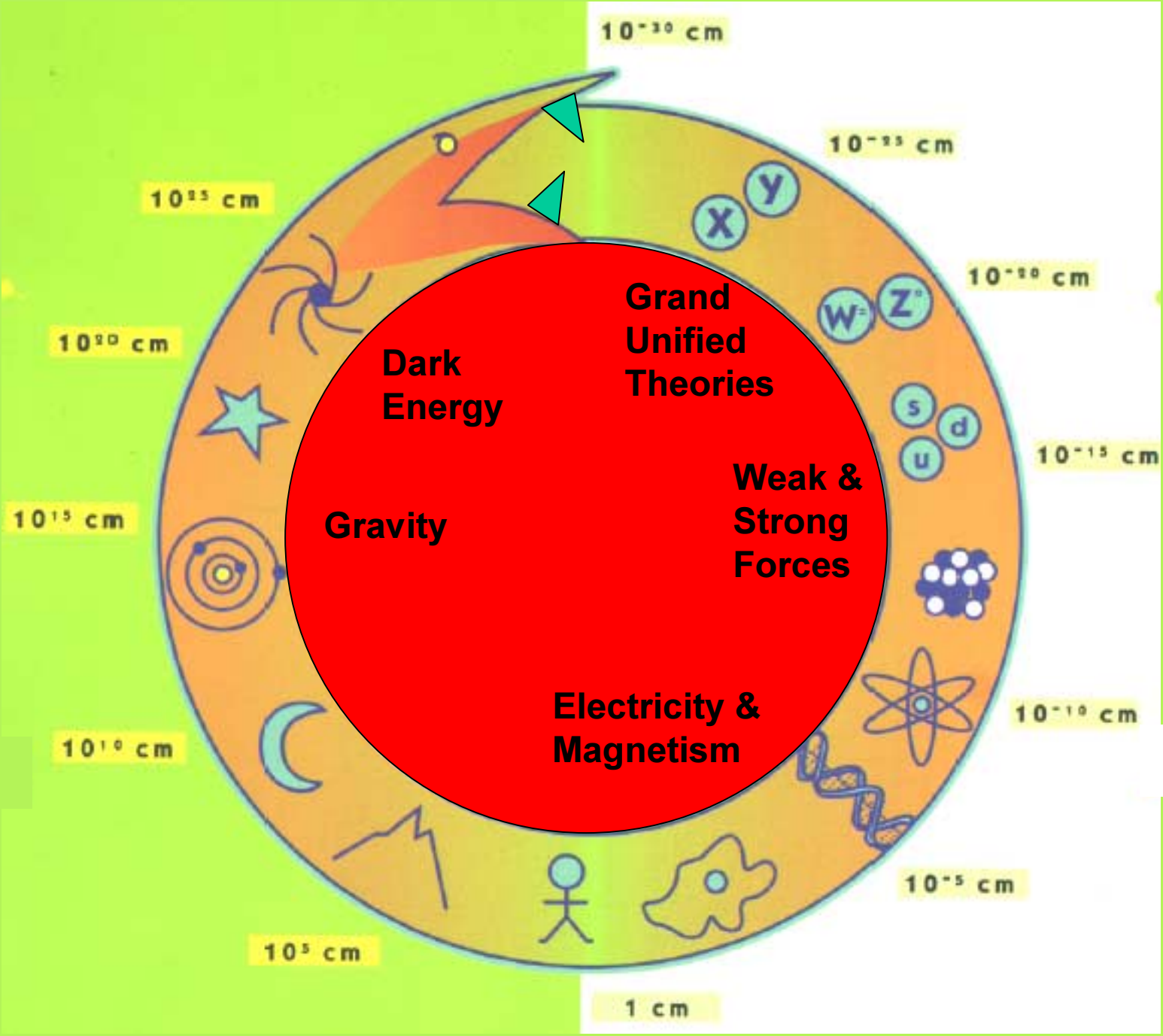


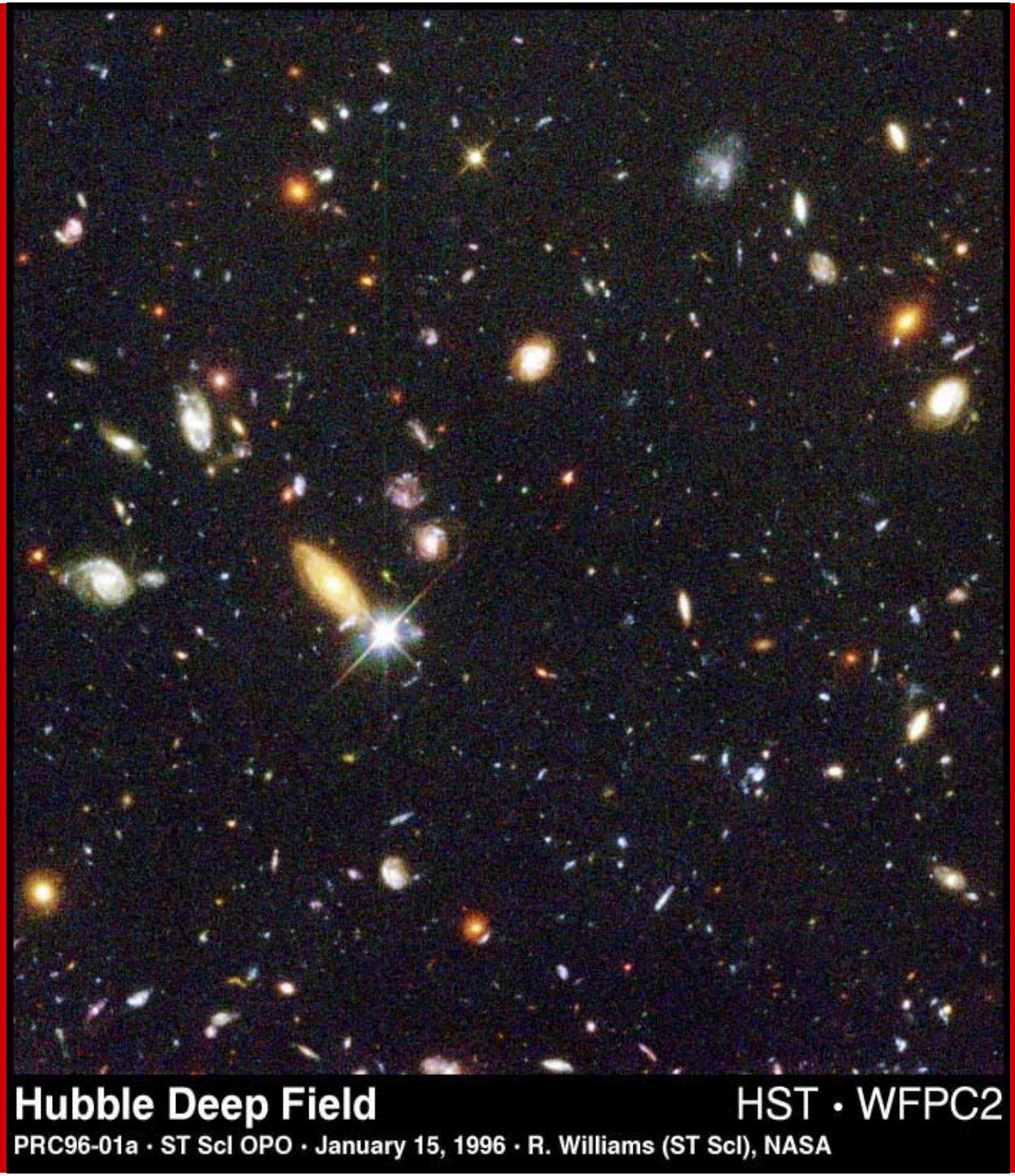
The MPS Portfolio

- Mathematical Sciences
- Origins of the Universe
- Quantum Science and Engineering
- Molecular Connections
- Integrating Research with Education
- Tools

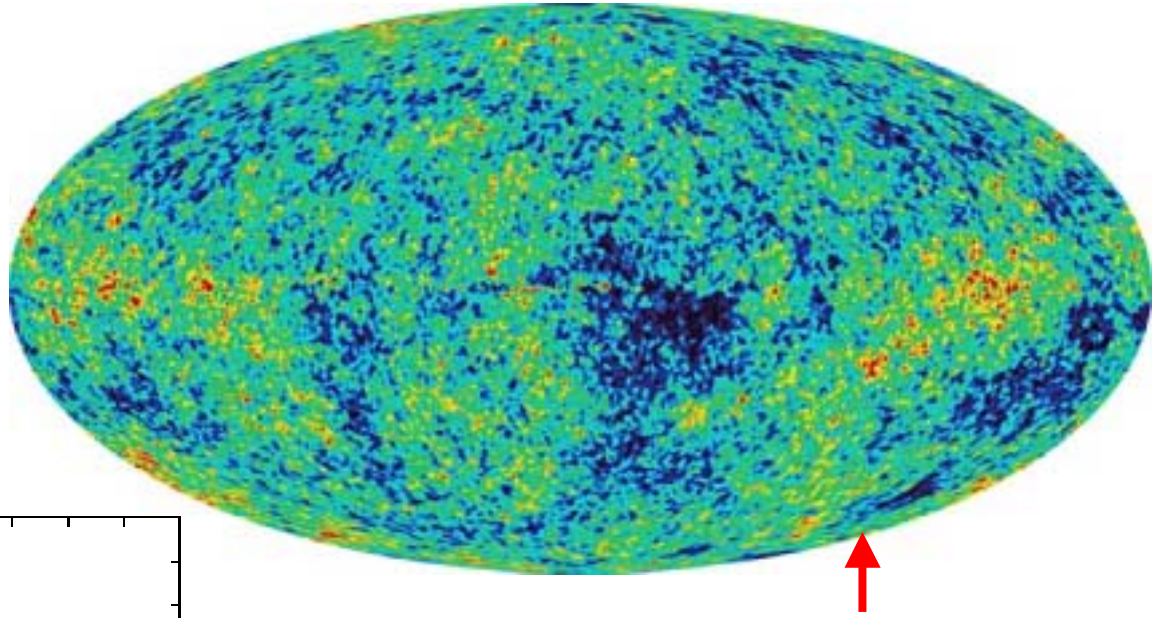


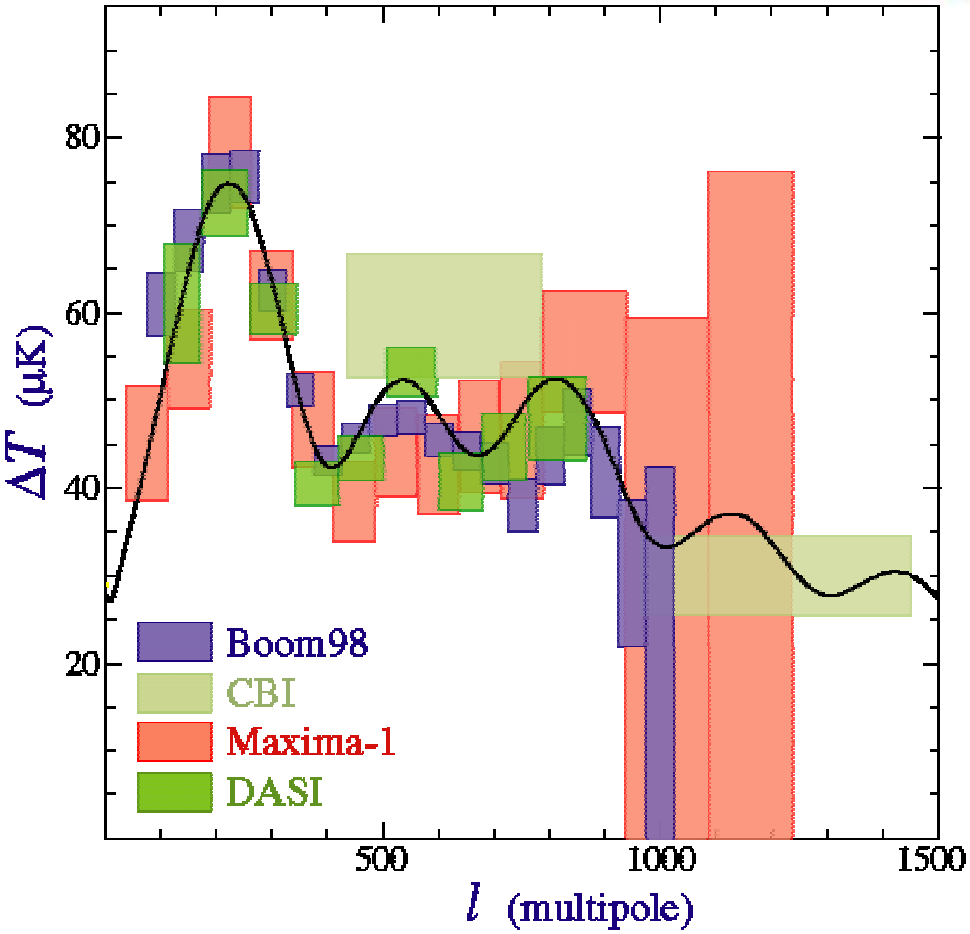
(By Felicitas Pauss)


10^{-30} cm
10^{-25} cm
10^{-20} cm
10^{-15} cm
10^{-10} cm
10^{-5} cm
1 cm
10^{5} cm
10^{10} cm
10^{15} cm
10^{20} cm
10^{25} cm
Grand Unified Theories
Dark Energy
Weak & Strong Forces
Gravity
Electricity & Magnetism
X
Y
W
Z
s
d
u


Hubble Deep Field
HST • WFPC2
PRC96-01a • ST ScI OPO • January 15, 1996 • R. Williams (ST ScI), NASA

Cosmic Microwave Background

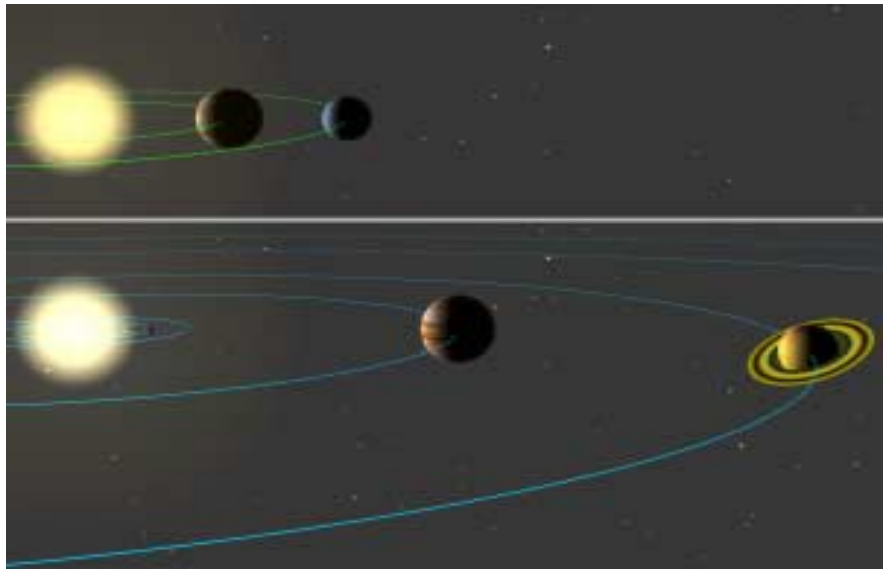




- COBE, CBI, WMAP, Boomerang, Maxima, DASI …
- Universe is flat and isotropic
- Matter: 4%
- Dark matter: 23%
- Dark energy: 73%

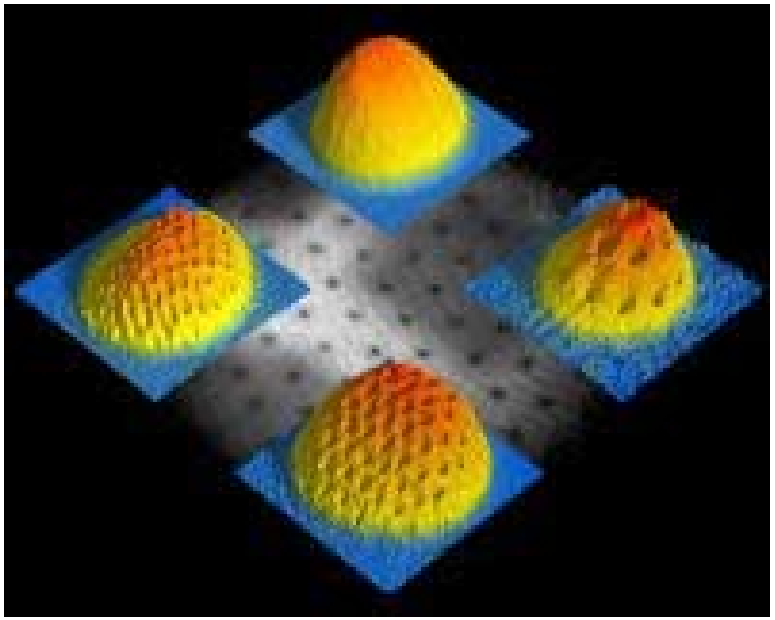
Extra-solar Planets Update

- Over 75 extra-solar planets found to date
- About 50 of them discovered by Geoff Marcy and Paul Butler and undergraduate students
- See also the Geneva Extrasolar Planet Search Programme

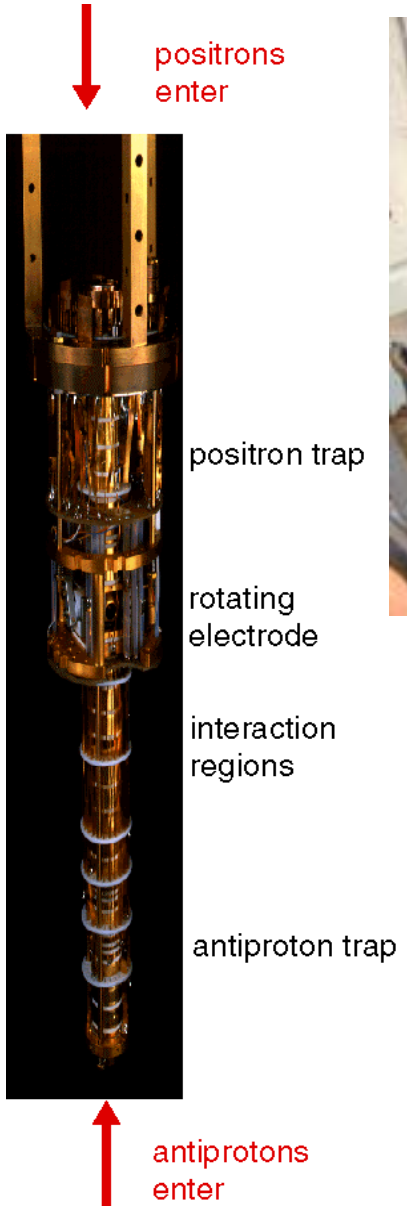


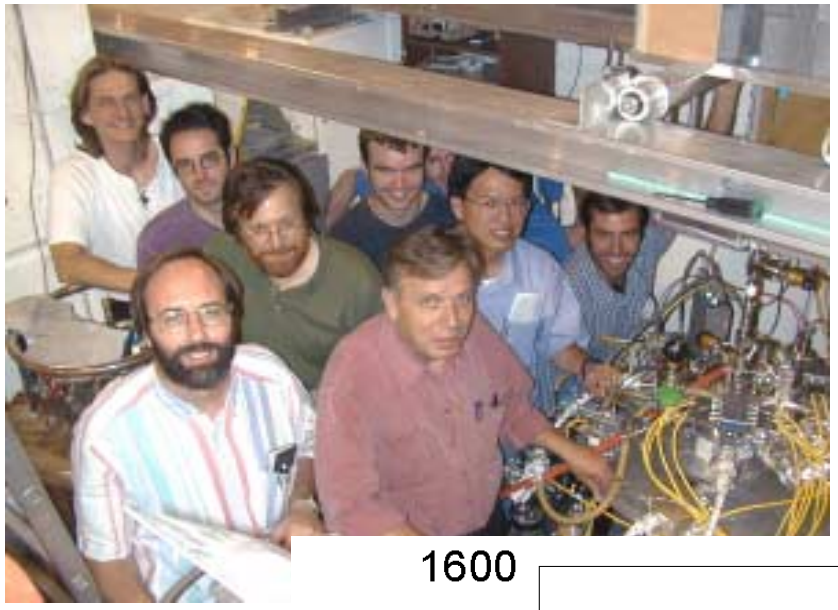
Vortices in a Quantum Fluid

- **Wolfgang Ketterle, MIT**
- **Macroscopic vortices are a manifestation of the quantum fluid behavior of Bose-Einstein Condensates.**
- **The images show quantum vortices in a rotating condensate of sodium atoms.**

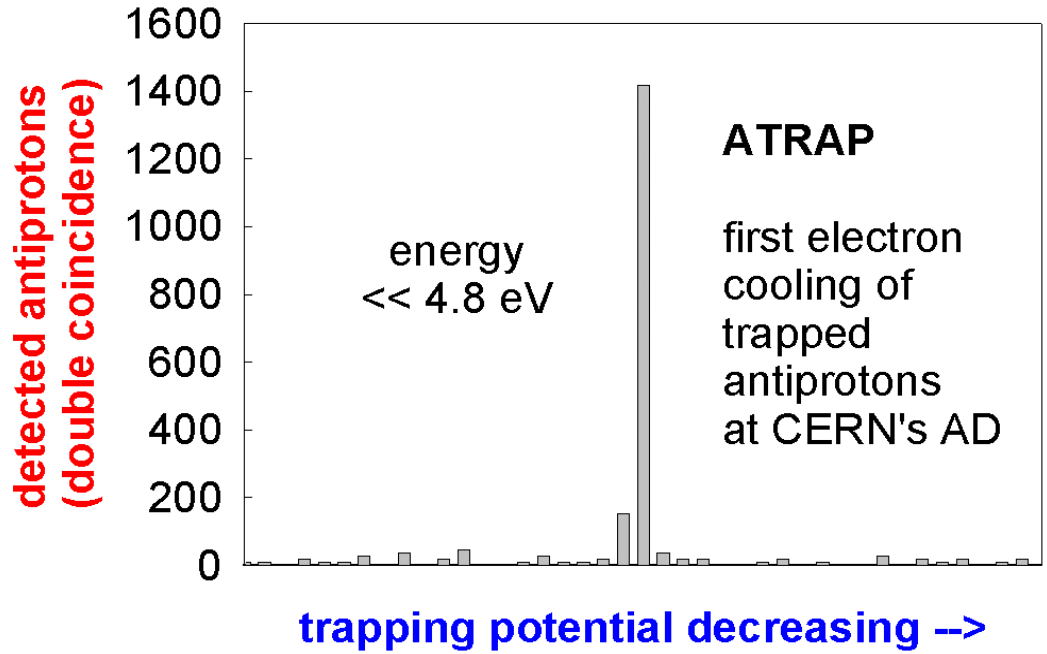


Creation of Anti-hydrogen at CERN





ATHENA and ATRAP

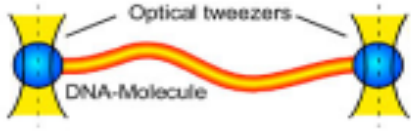


Real-time Dynamics of Biological Molecules

- **Steve Quake, Caltech**

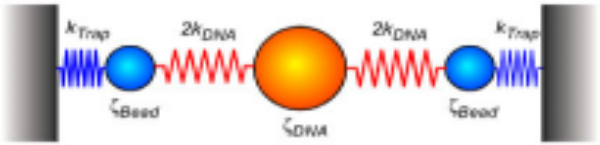
- **DNA molecule held at each end by laser tweezers executes an elastic motion from which we can learn mechanical and dynamic properties.**

Sketch of the experimental set-up:

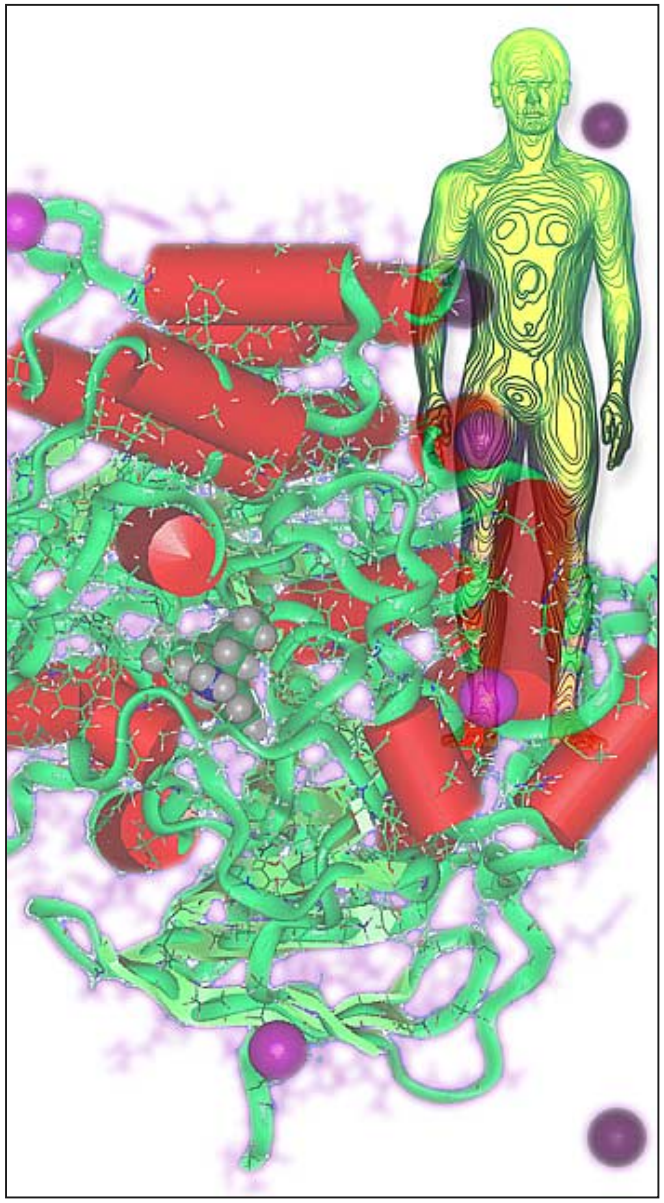


A microscopic image:

The mechanistic model:



Stretched DNA molecule in trap.

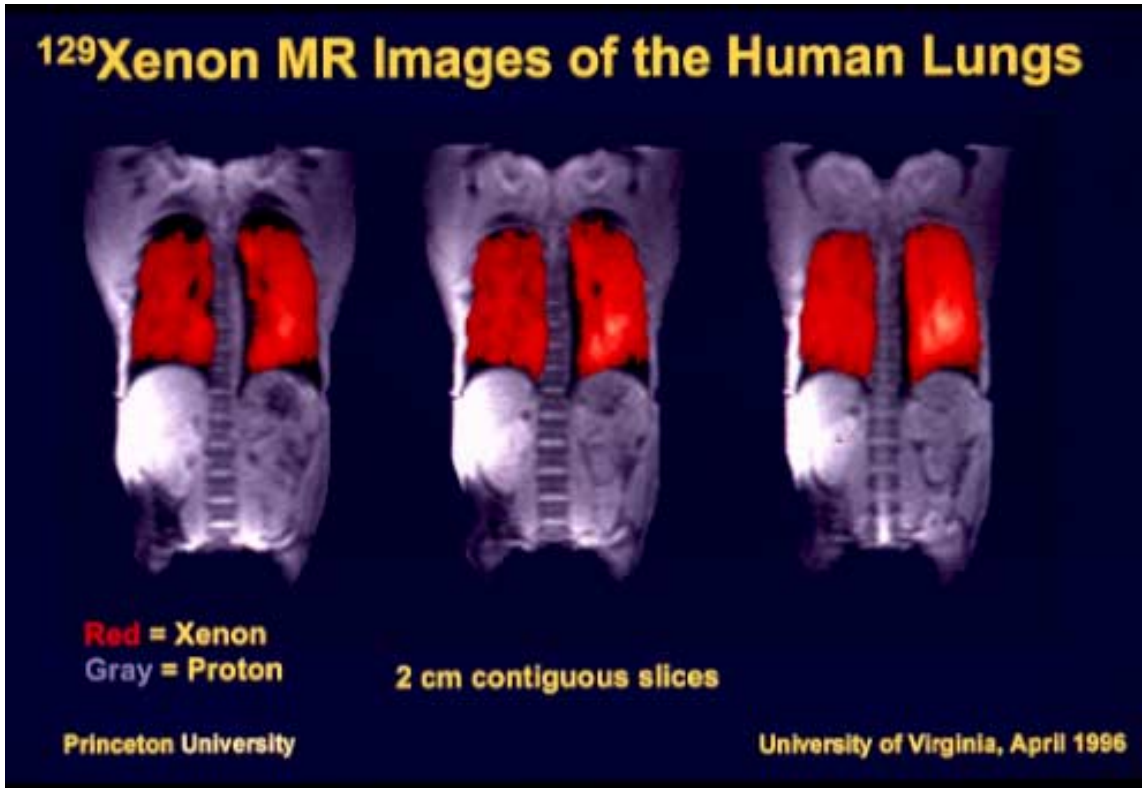


The Living Cell – A Grand Challenge For the Physical Sciences

- Decoding the human genome
- Proteomics
- Computation and information processes
- Immunological responses
- Cell structure issues
- And many more …

Medical Physics

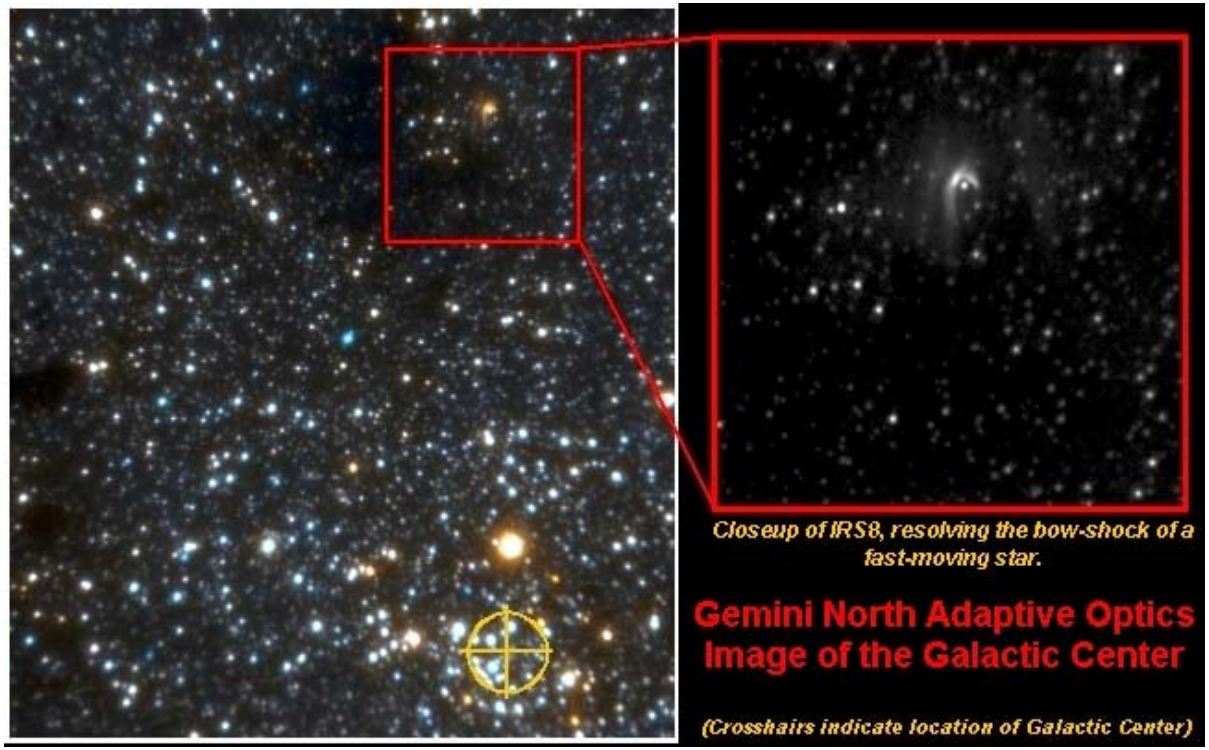
Use of polarized noble gases for MRI medical diagnostics (Princeton, Michigan, Virginia)



Tools

Gemini Telescopes are Operational

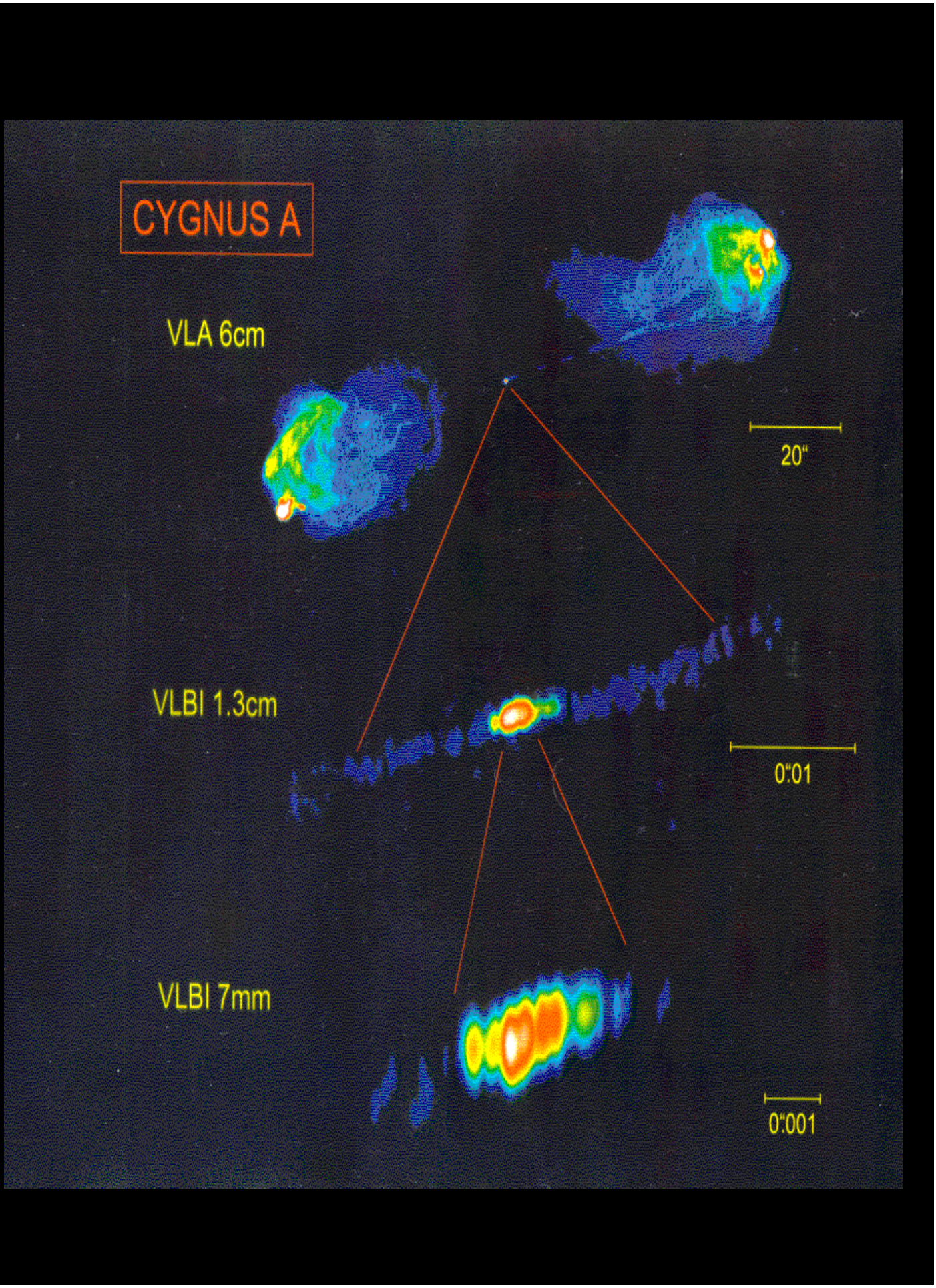
- **Science has begun at both telescopes.**



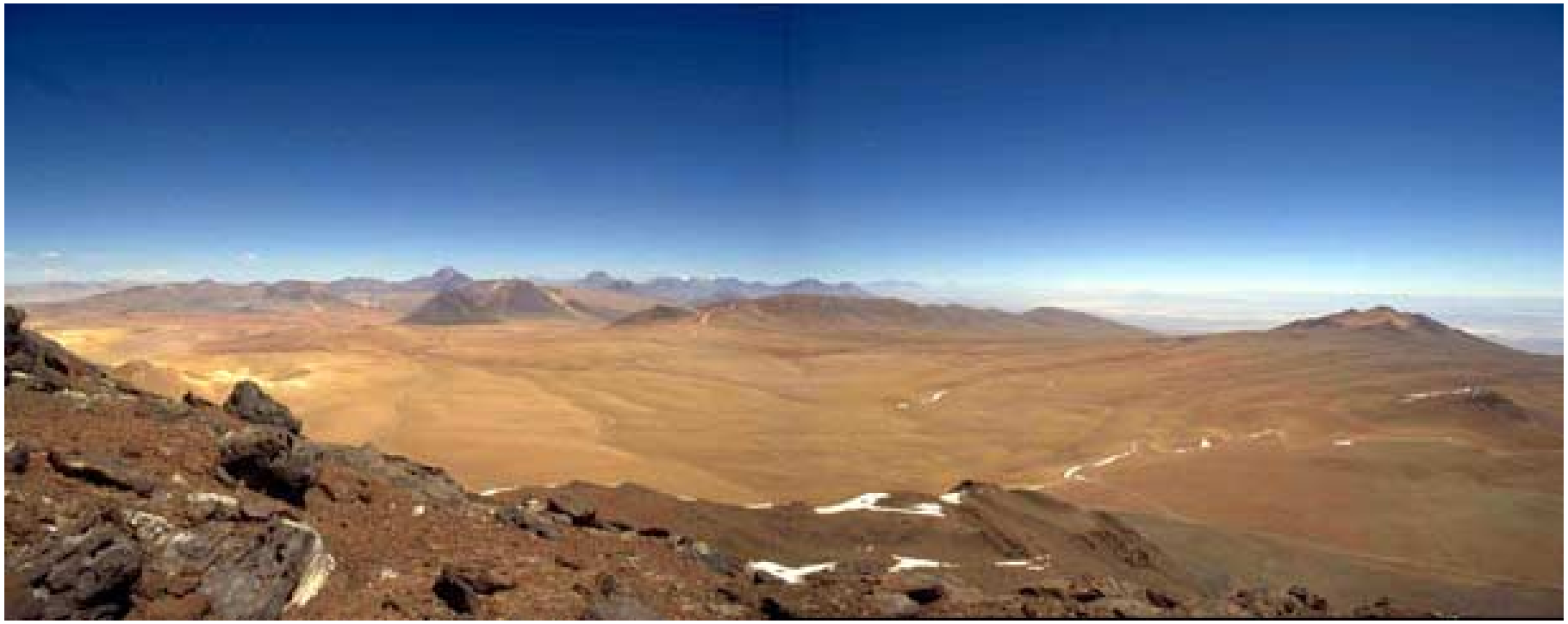
- **AO image shows previously unresolved object as a 'bow-shock' from a star moving rapidly relative to a gas cloud.**

The Very Large Array (VLA) (Socorro, New Mexico)


METROPOLITAN
WASHINGTON
ROCKVILLE
MD
VA
BETHESDA
SILVER SPRING
WASHINGTON
ARLINGTON
ALEXANDRIA
Springfield
MILITARY RESERVATION


CYGNUS A
VLA 6cm
20"
VLBI 1.3cm
0".01
VLBI 7mm
0".001

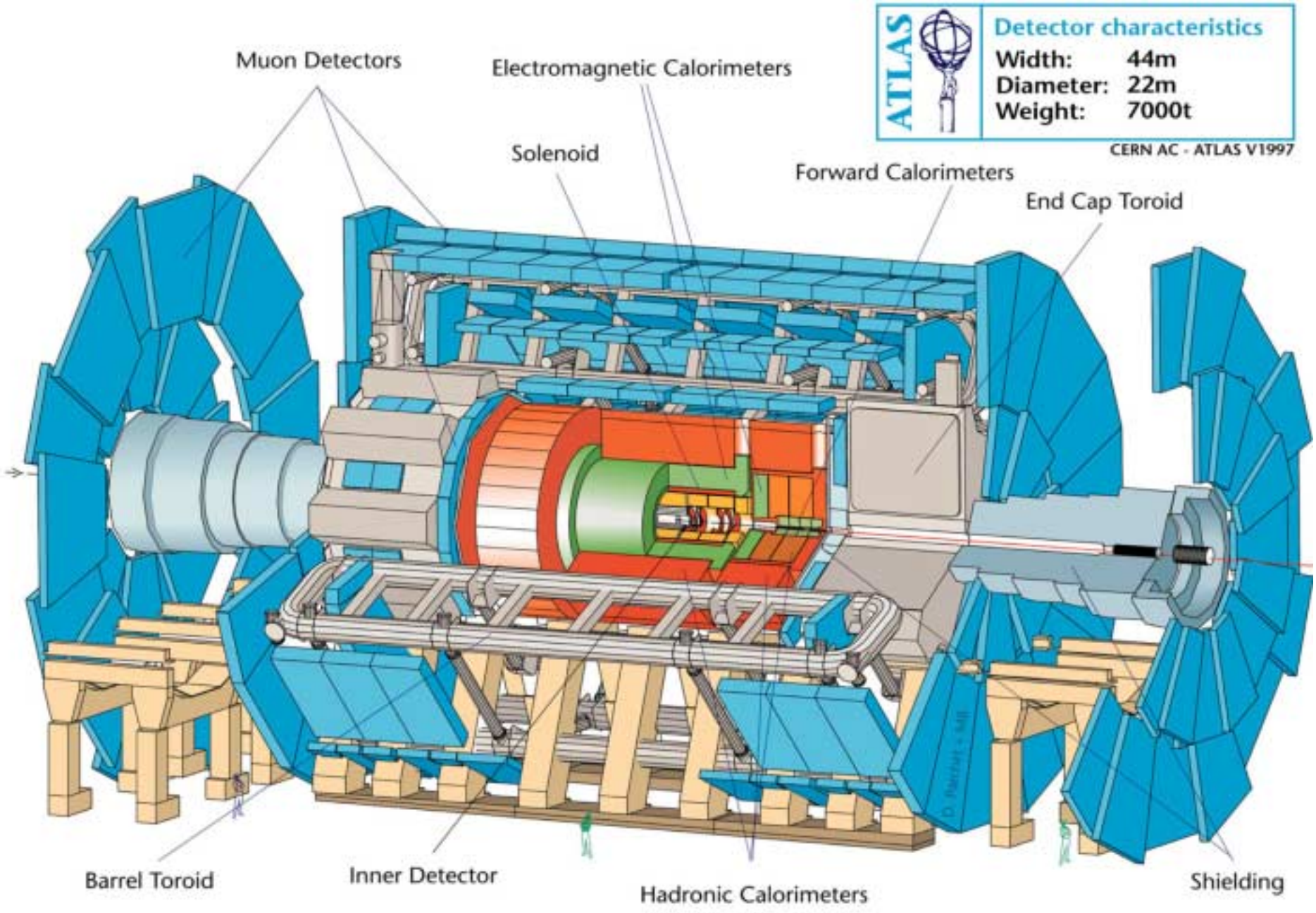
Atacama Desert at Chajnantor, Chile



Future home of the Atacama Large Millimeter Array (ALMA)

Large Hadron Collider (LHC) at CERN

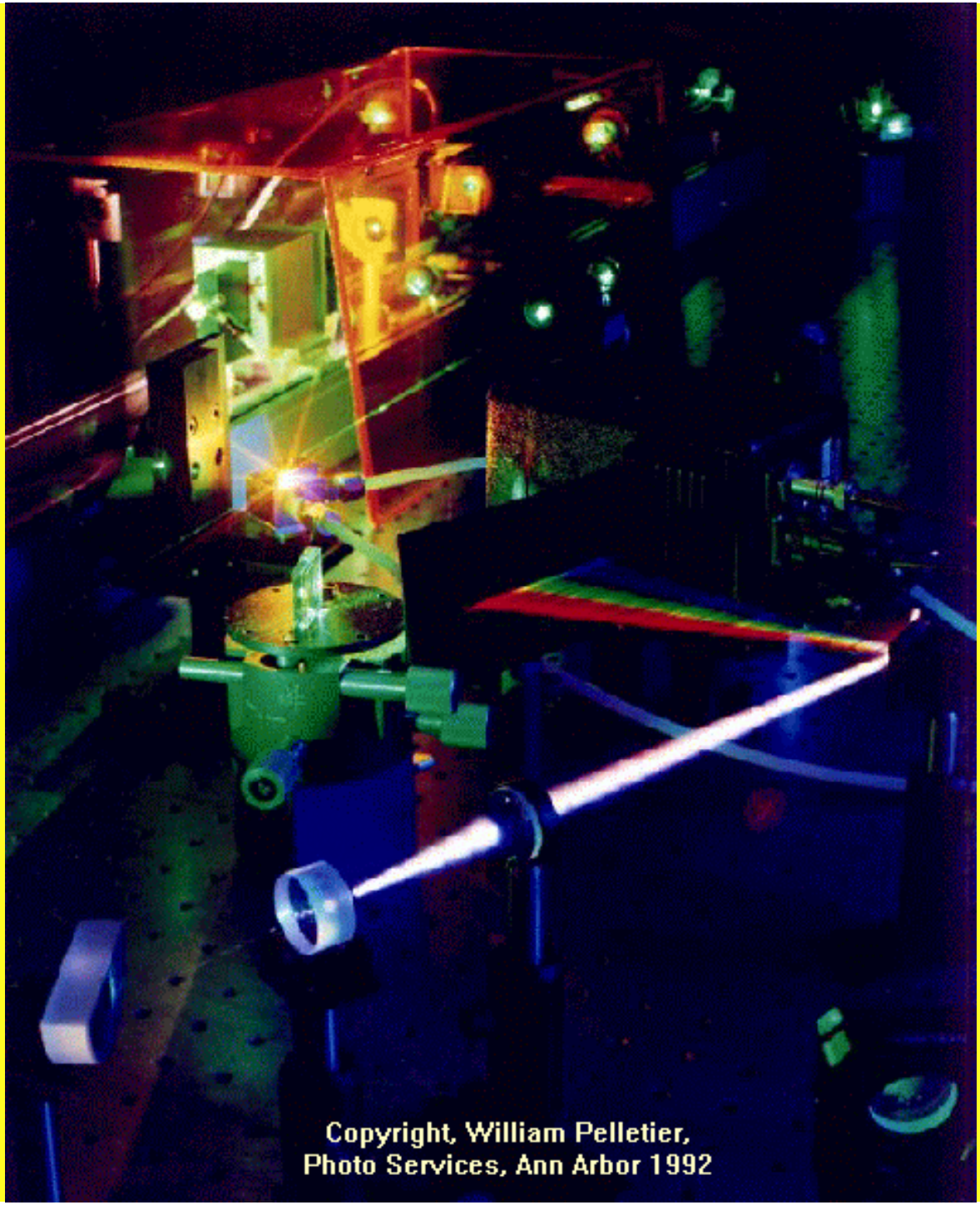
- $E_{LHC} = 7 * E_{FNAL}$
- **Search for:**
  - **Higgs boson**
  - **Supersymmetry**
  - **Other new physics**
- **Construction complete in 2007**


ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

National High Magnetic Field Laboratory

45 Tesla Hybrid

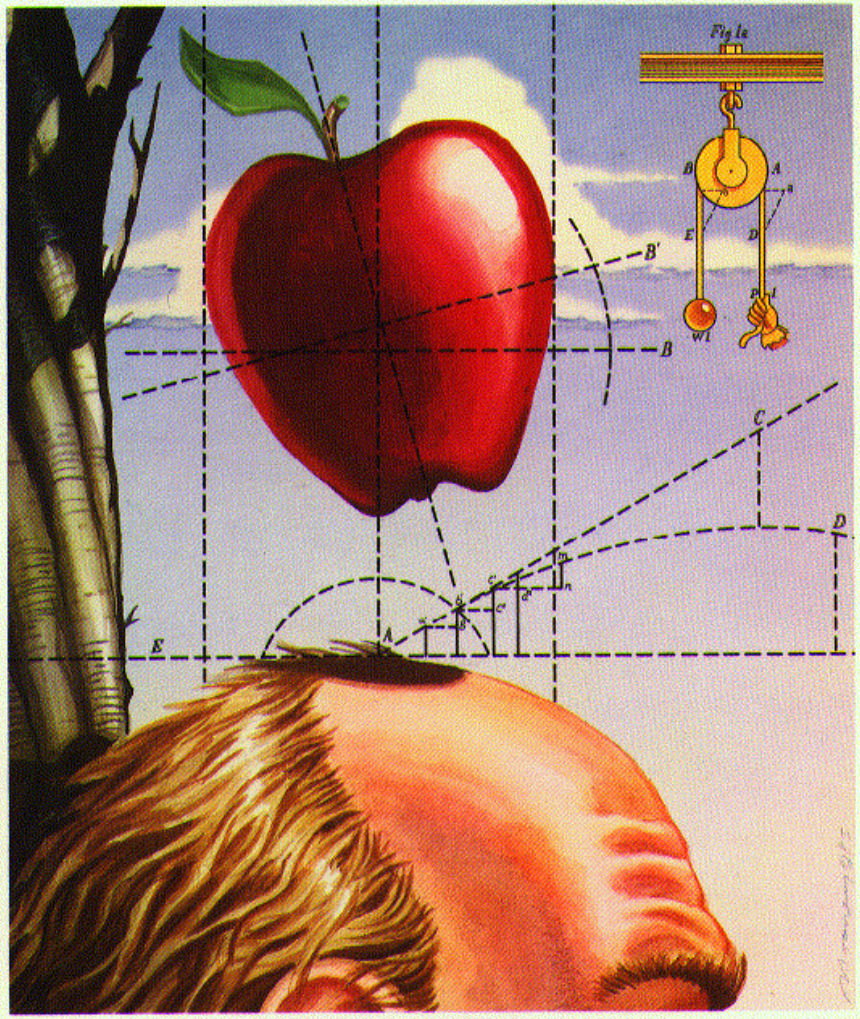
10 December 1999



Terawatt Lasers on a Tabletop Using Chirped-Pulse Amplification

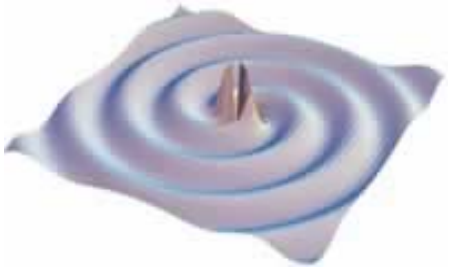
Center for Ultra-fast Optical Sciences (CUOS)

University of Michigan

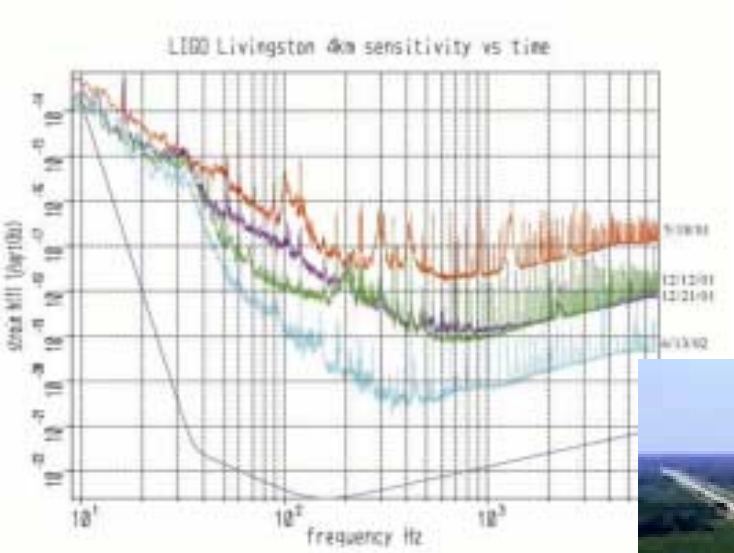


Gravity.
It isn't just a good idea.
It's the law.

Sponsored By The Physical Universe In Cooperation With The National Safety Council.



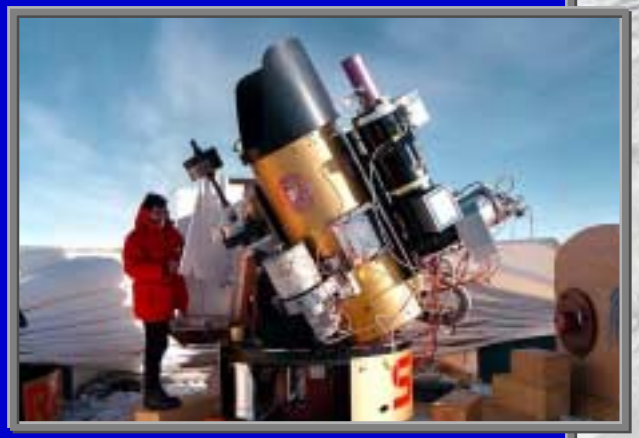
The Laser Interferometer Gravity-wave Observatory (LIGO)

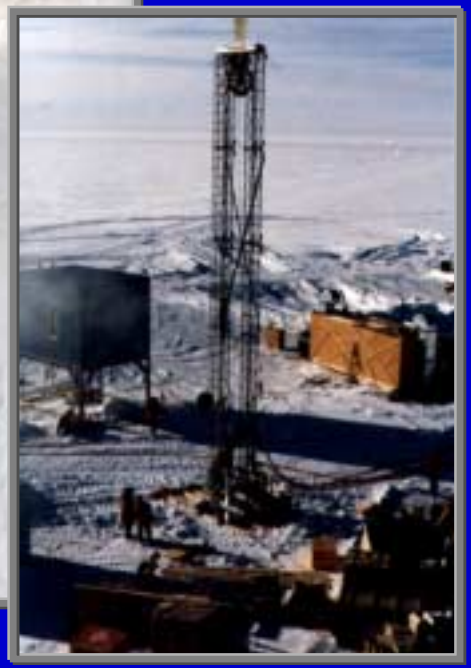


GEO Project
(Germany-UK)
Hannover
0.6 km arms

VIRGO Project
(France-Italy)
Pisa, Italy
3 km arms

South Pole Research





Amanda

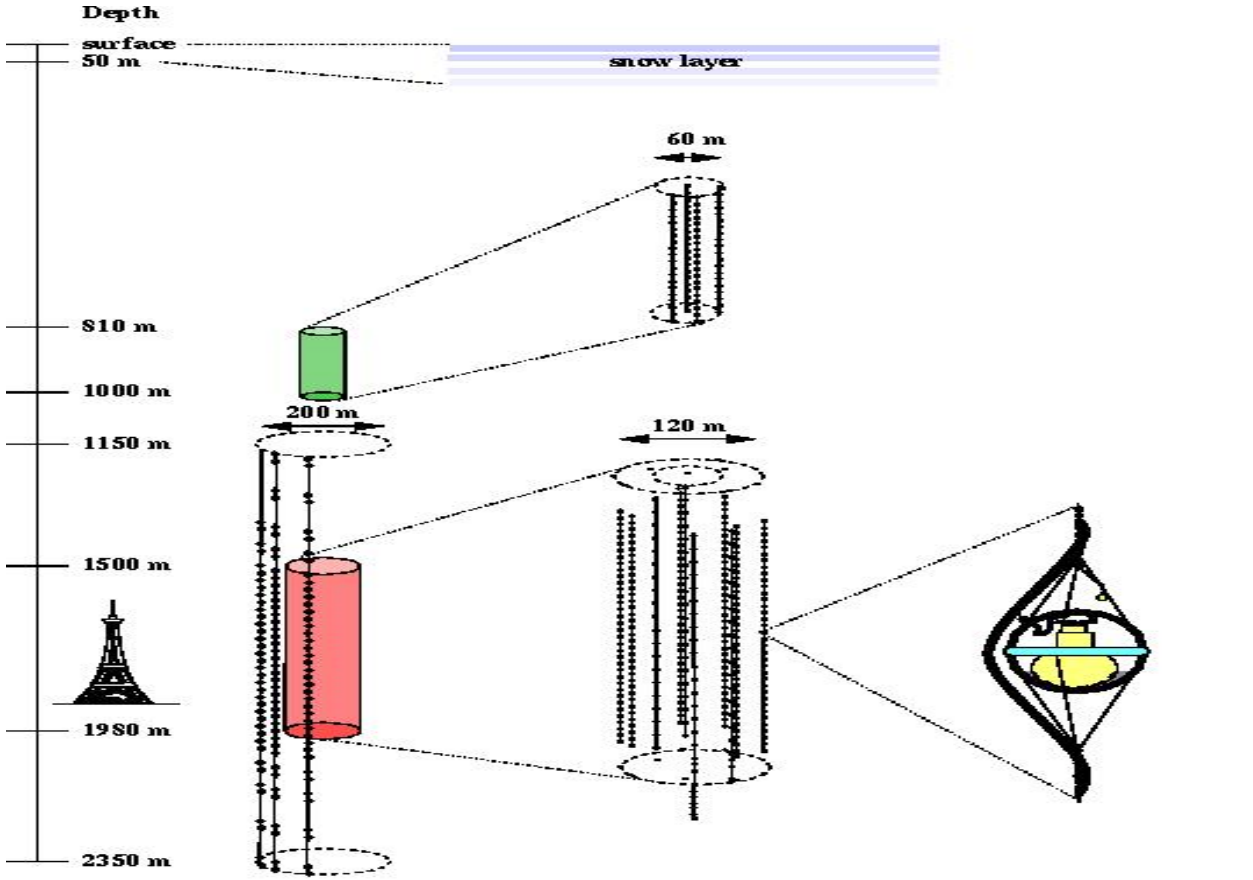
IceCube

Belgium

Germany

Sweden

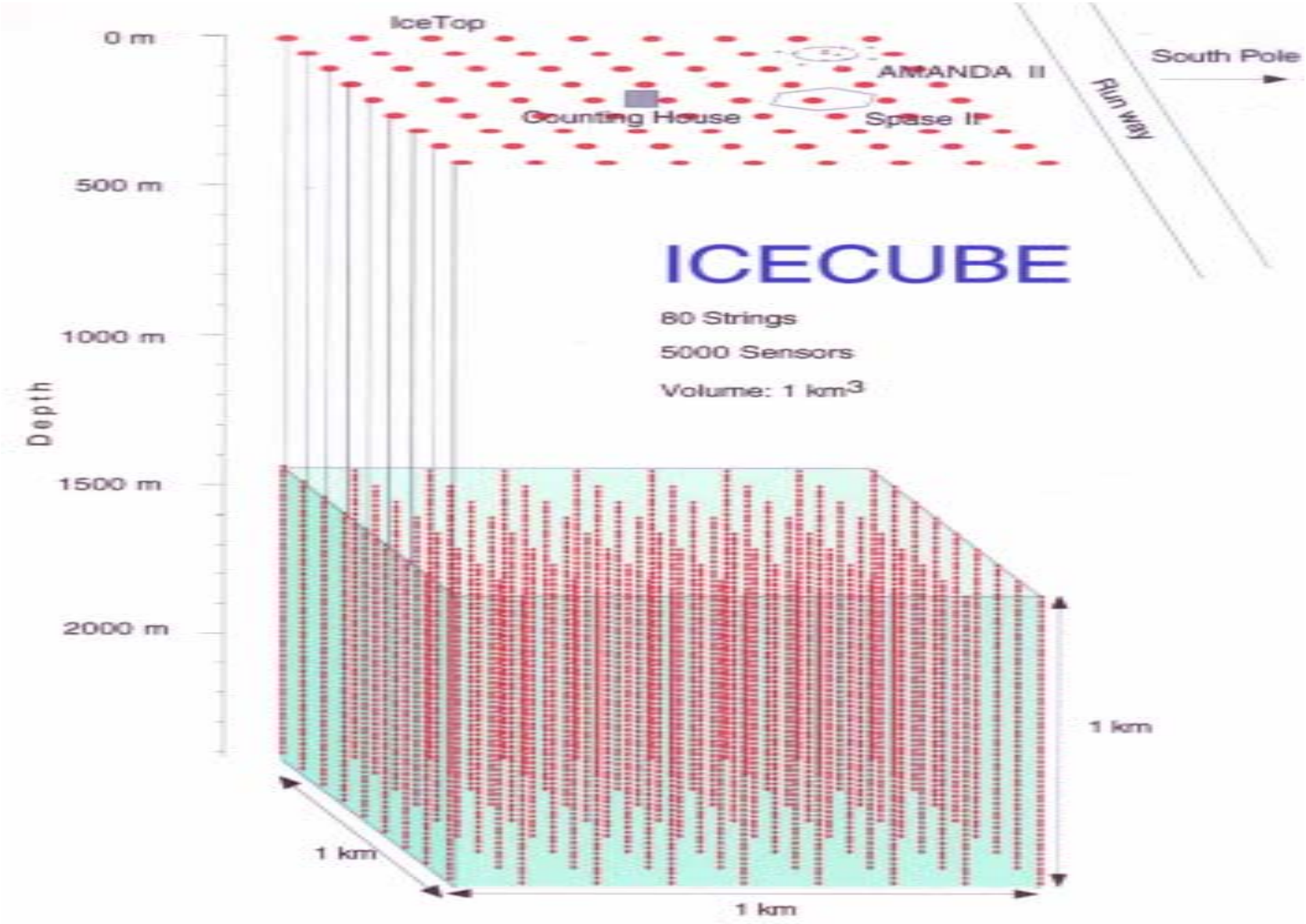
United States



AMANDA as of 1998
Eiffel Tower as comparison
(true scaling)

zoomed in on
AMANDA-A (top)
AMANDA-B10 (bottom)

zoomed in on one
optical module (OM)


IceTop
0 m
500 m
1000 m
1500 m
2000 m
Depth
AMANDA II
Counting House
Spase II
Run way
South Pole
ICECUBE
80 Strings
5000 Sensors
Volume: 1 km3
1 km
1 km
1 km

Nobel Prize in Physics for 2002

"For pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"

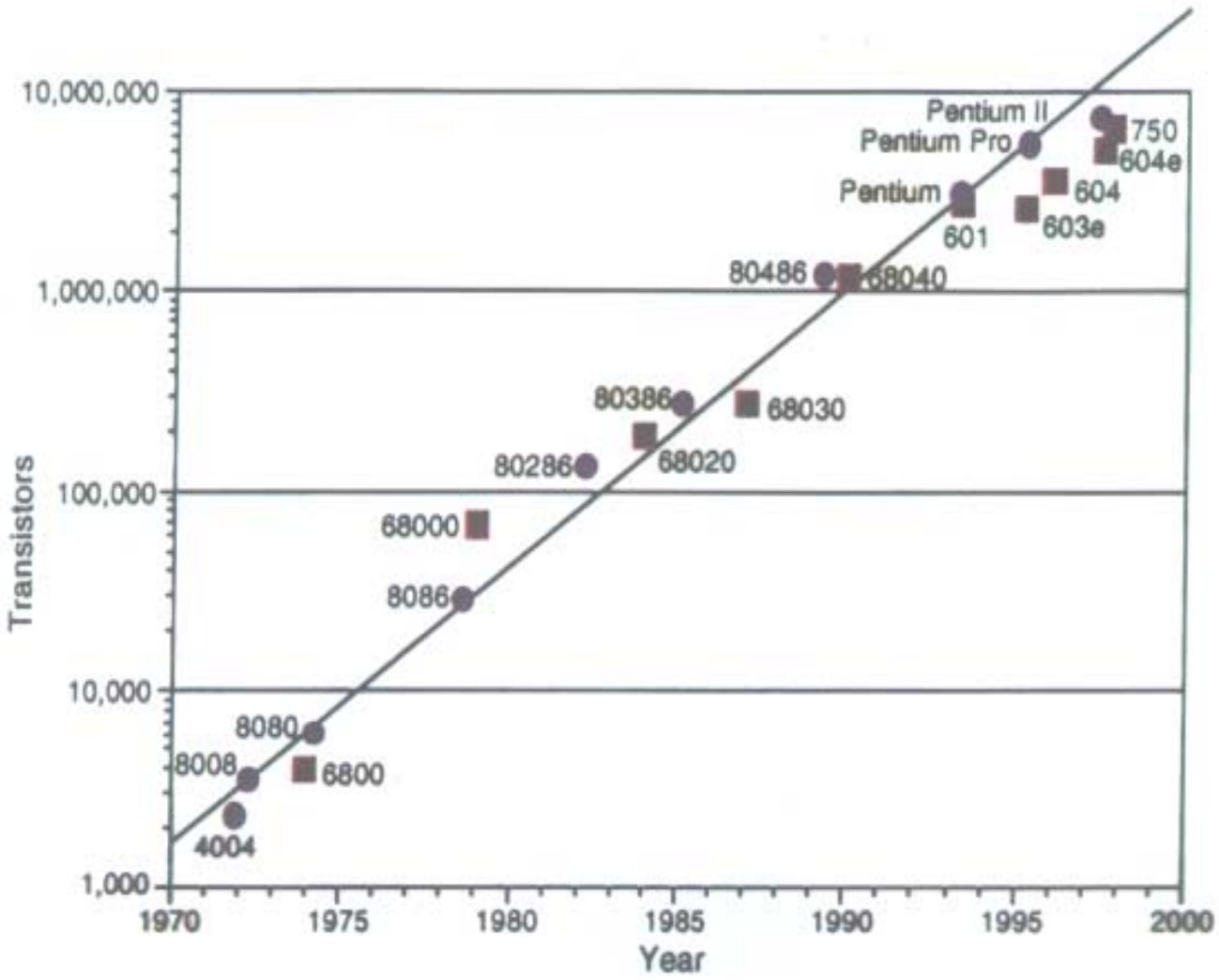
- **Raymond Davis**, Brookhaven NL
- **Masatoshi Koshiba,** Super–K, Japan

"For pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"

- **Riccardo Giacconi**, Assoc. Univ. Inc.

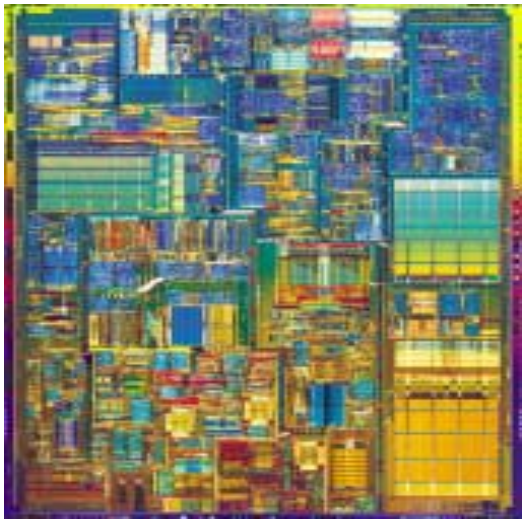
Information Technology

The Evolution of Moore's Law

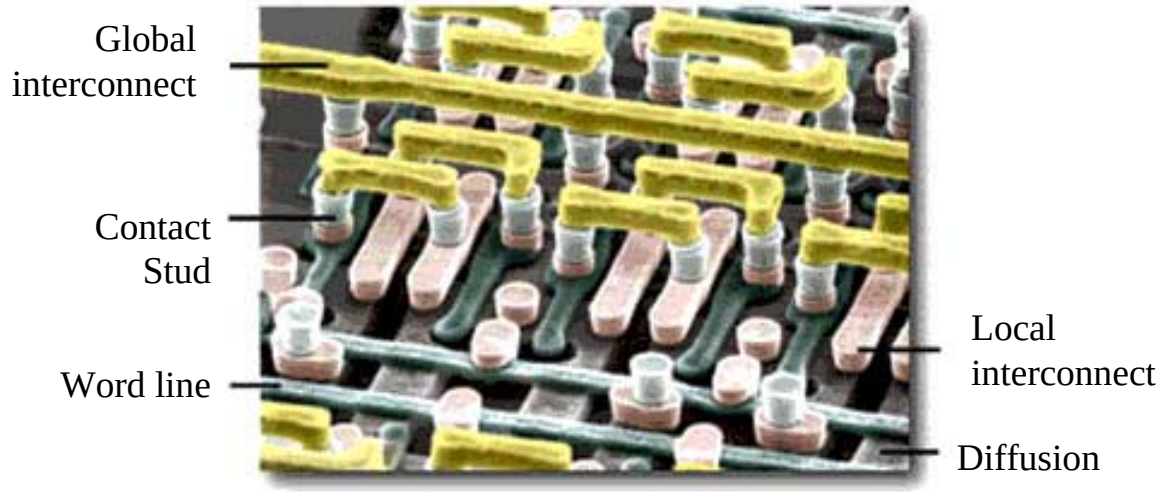


Advances in Chemistry Have Utterly Transformed the Manufacturing Methods Used to Construct the Most Complex Artificial Structures Produced by Human Beings

2000: Pentium® 4 Processor



Advances in chemistry have values that go far beyond the fact that they are interesting to chemists.



- **Photolithography**
- **Growth and Processing**

(Slide by Ralph Nuzzo, Univ. Illinois)

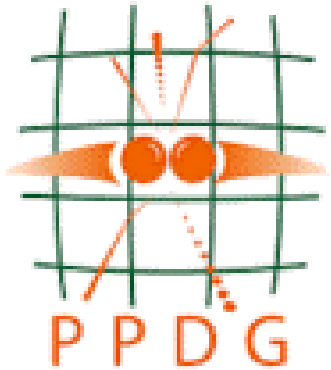
Physics World
MARCH 1998
VOLUME 11 NO 3

Quantum information

New forms of computation and communication

QuickTime™ and a
GIF decompressor
are needed to see this picture.

GRID Fever



- Many national efforts
- Heightened industrial interest

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

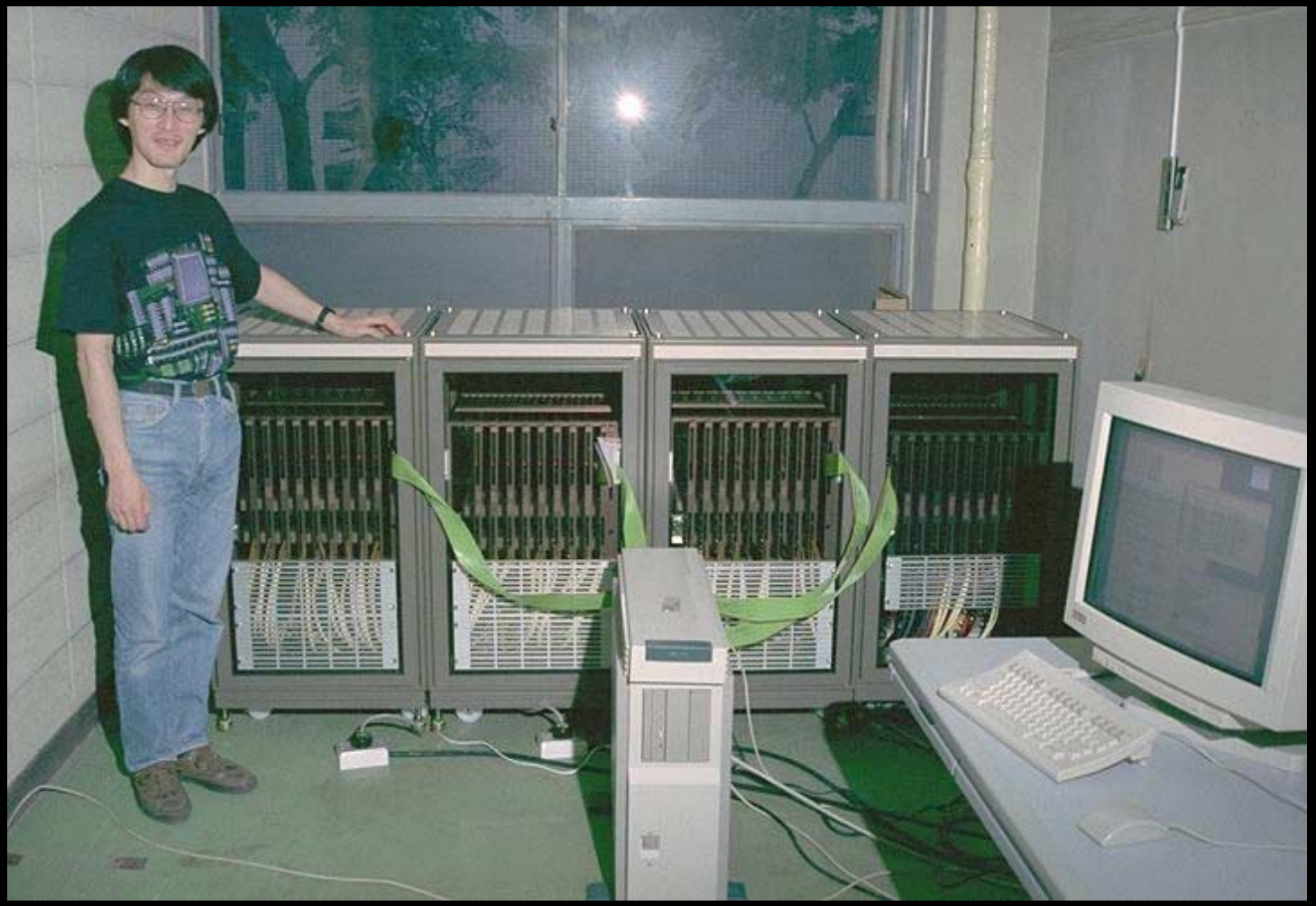
Sloan Digital Sky Survey (Apache Point, NM)

~ 20 GB/hr (not so large - but has to go 2000 miles)

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

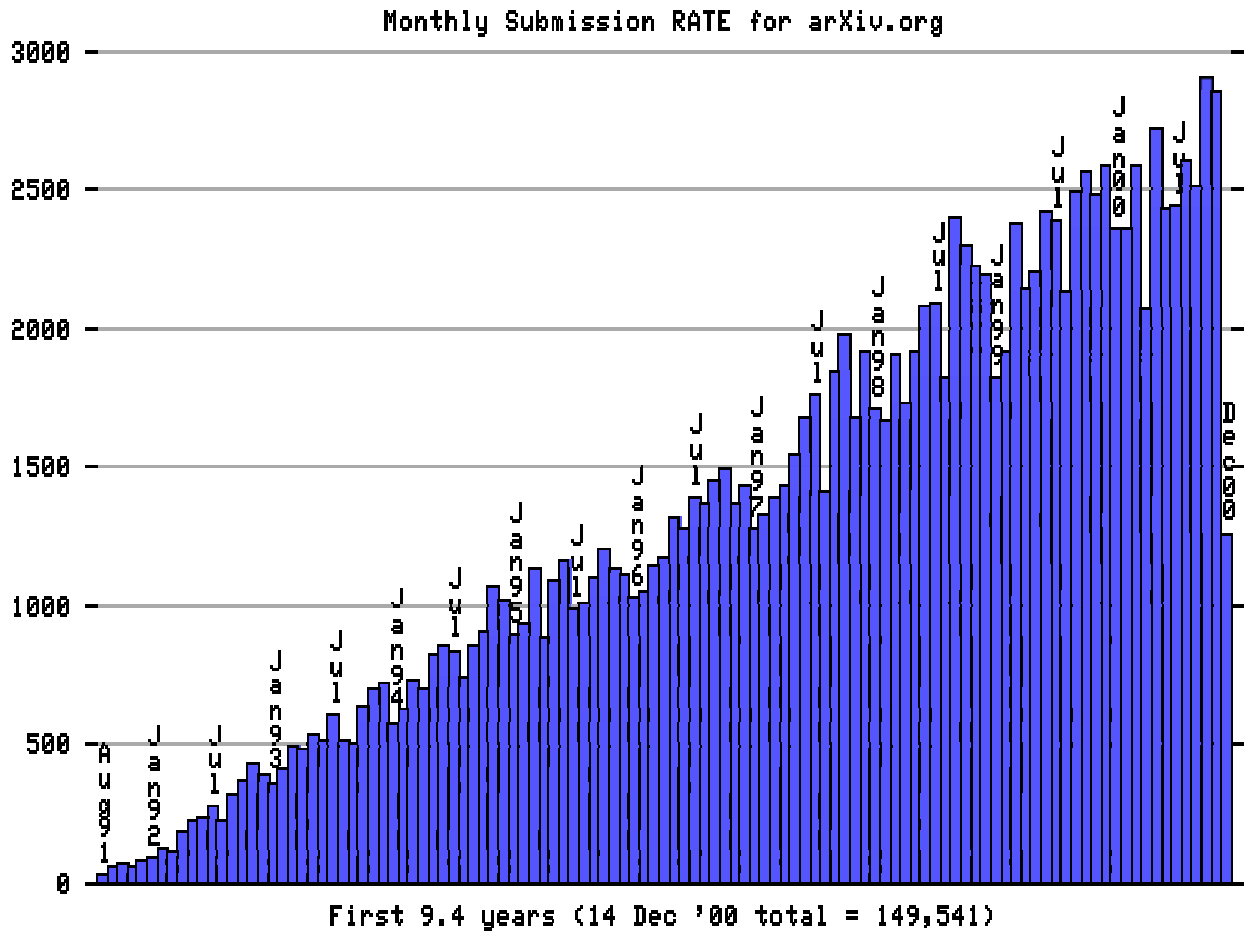
Fermilab Feynman Center (Batavia, Illinois)

Astrophysics on the GRAPE Family of Special-Purpose Computers



Jun Makino and the GRAPE-4 Computer

Growth in usage of the Los Alamos Preprint Server (xxx.lanl.gov, created by Paul Ginsparg)

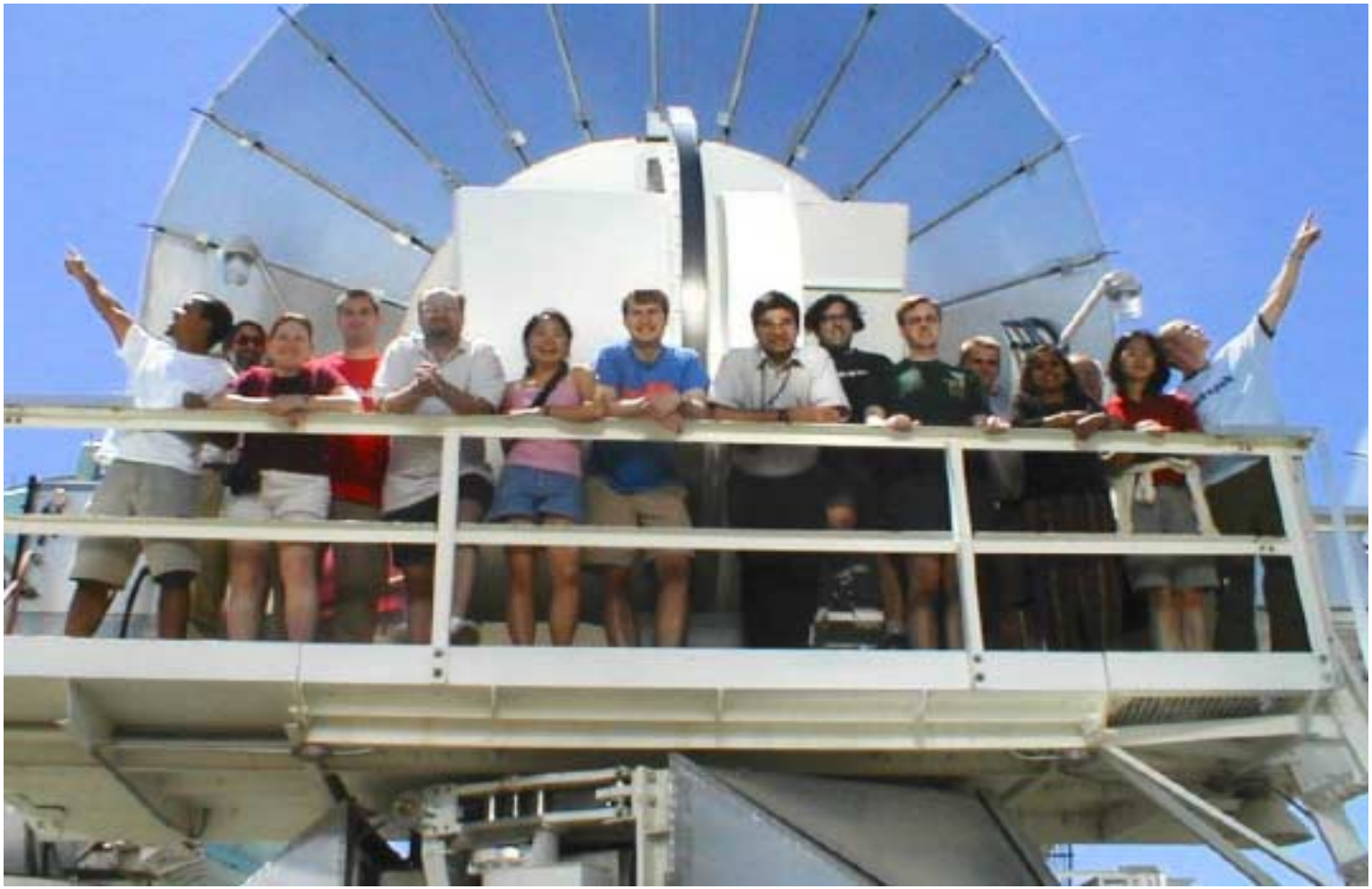


People

Number of People Involved in MPS Activities

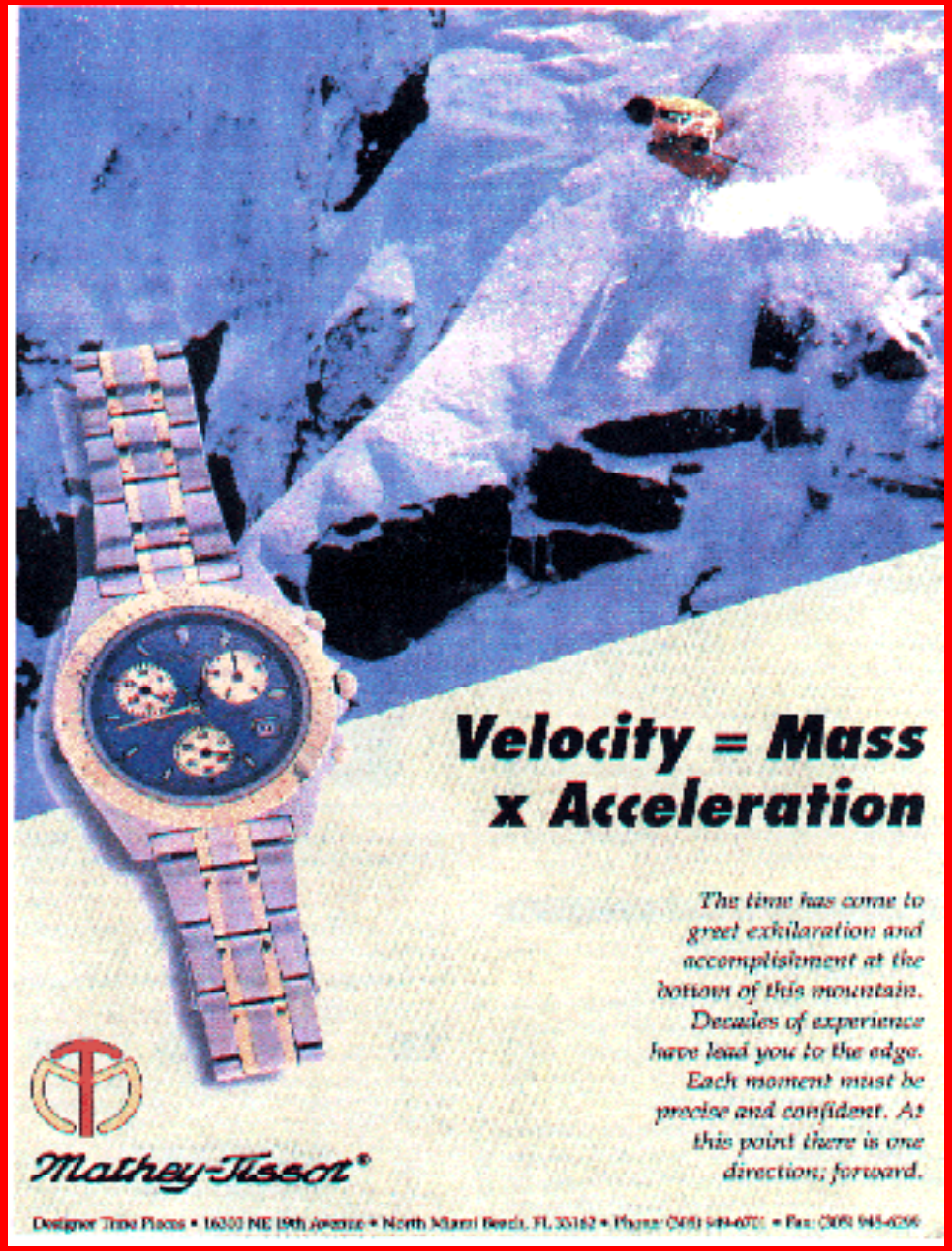
	FY 2001 Actual	FY 2002 Estimate	FY 2003 Estimate
Senior Researchers	6,132	6,400	6,400
Other Professionals	1,121	1,170	1,170
Post-Doctorates	2,148	2,240	2,240
Graduate Students	6,192	6,400	6,400
Undergraduate Students	3,051	3,200	3,200
K - 12 Students	285	285	285
K - 12 Teachers	668	700	700
Total Number of People	19,597	20,395	20,395

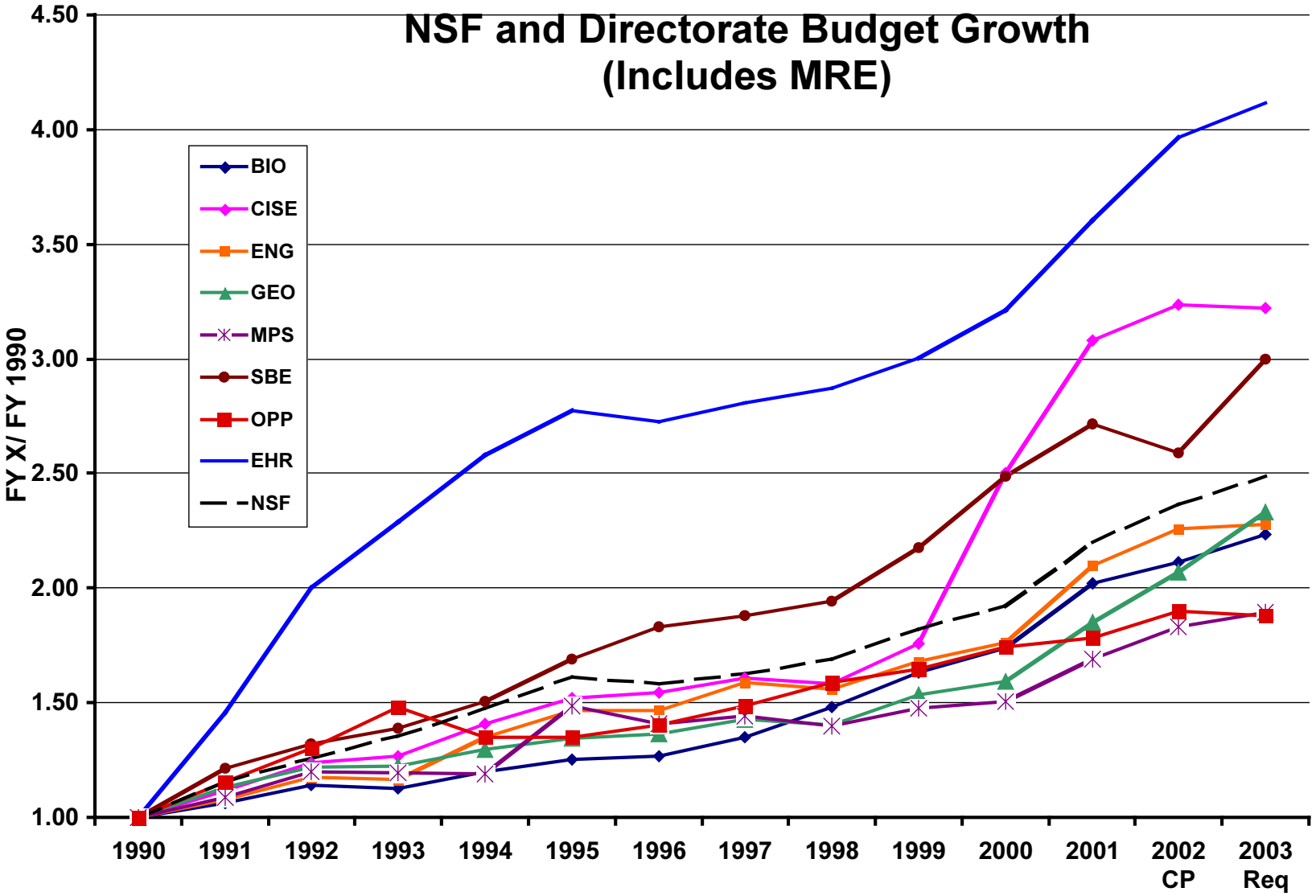
MPS spends at least $300 million annually on Graduate and Post-doctoral training !

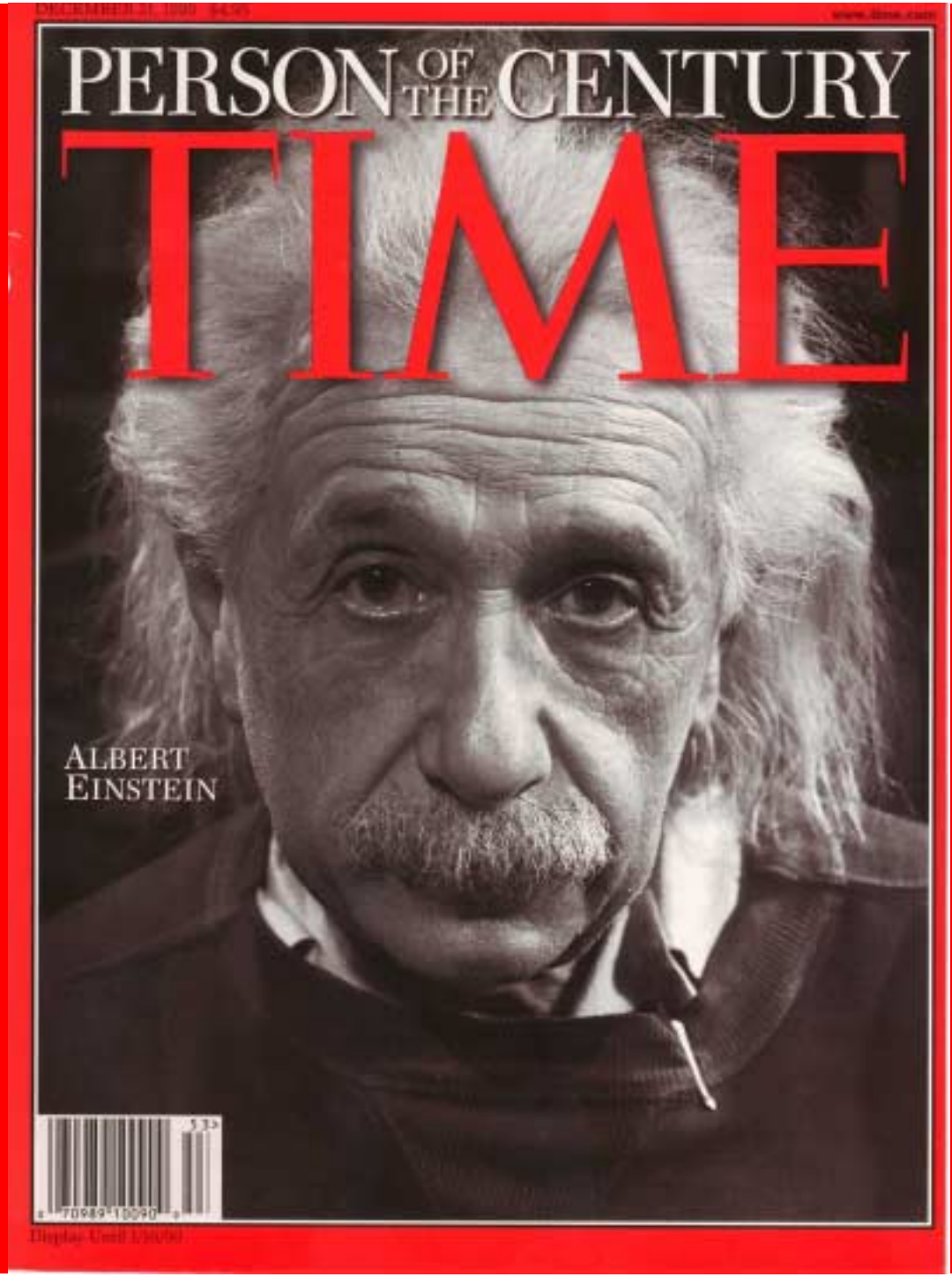


Students at the June 2001 Berkeley-Illinois-Maryland (BIMA) summer school pose on the platform of one of BIMA's 6.1m-diameter dishes.

Mobile Chemistry Laboratory. Gary Long (VPI) developed a Mobile Chemistry Laboratory (MCL) with Chemistry Division support. The current program expands the use of the MCL into more rural regions of southwestern Virginia and establishes two additional weeks of high school teacher workshops.


Velocity = Mass
x Acceleration
The time has come to
greet exhilaration and
accomplishment at the
bottom of this mountain.
Decades of experience
have lead you to the edge.
Each moment must be
precise and confident. At
this point there is one
direction; forward.
Mathey-Tissot®


NSF and Directorate Budget Growth
(Includes MRE)
FY X/ FY 1990
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
BIO
CISE
ENG
GEO
MPS
SBE
OPP
EHR
NSF
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002 CP
2003 Req


PERSON OF THE CENTURY
TIME
ALBERT
EINSTEIN

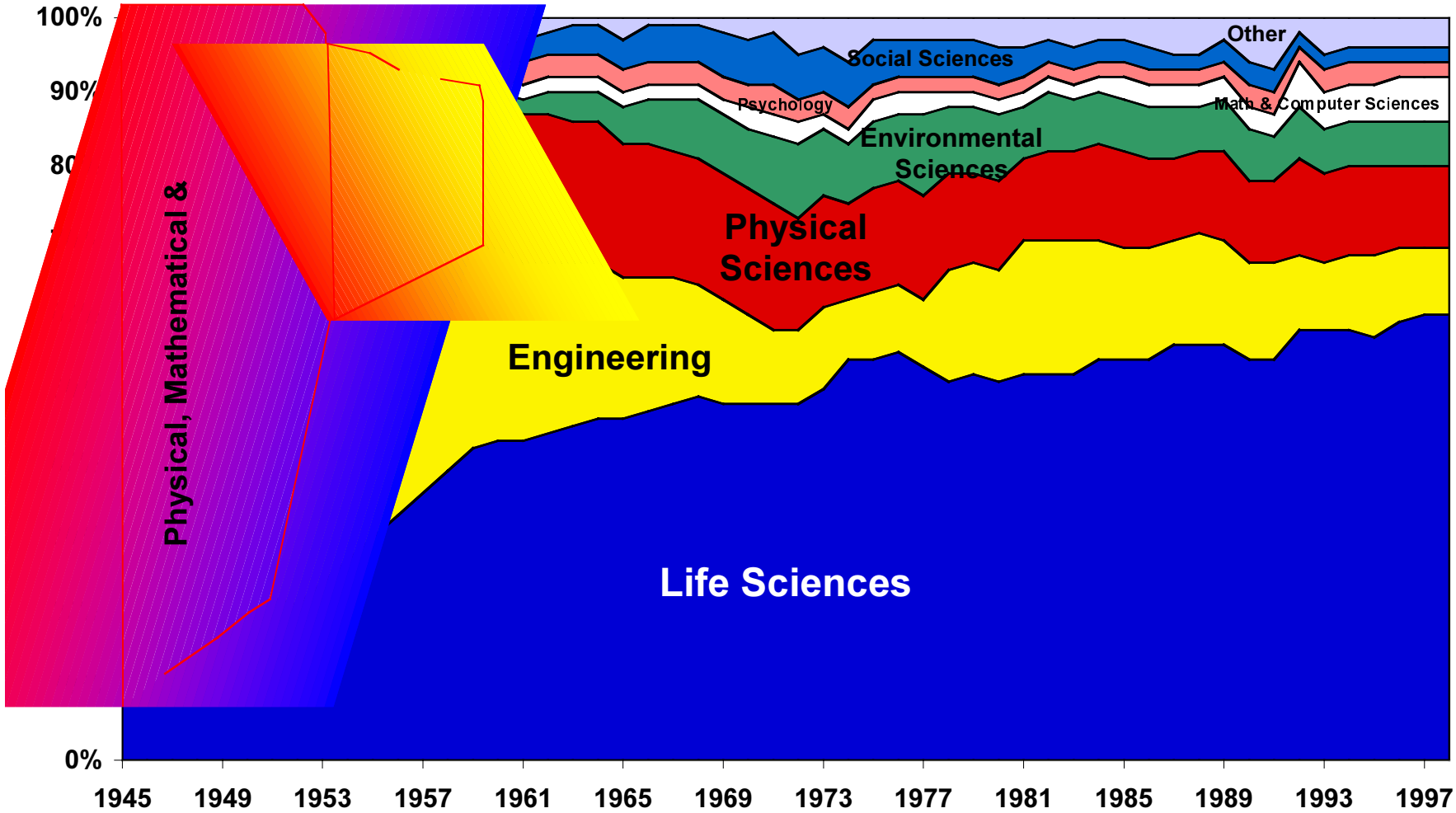
The Money Is Available

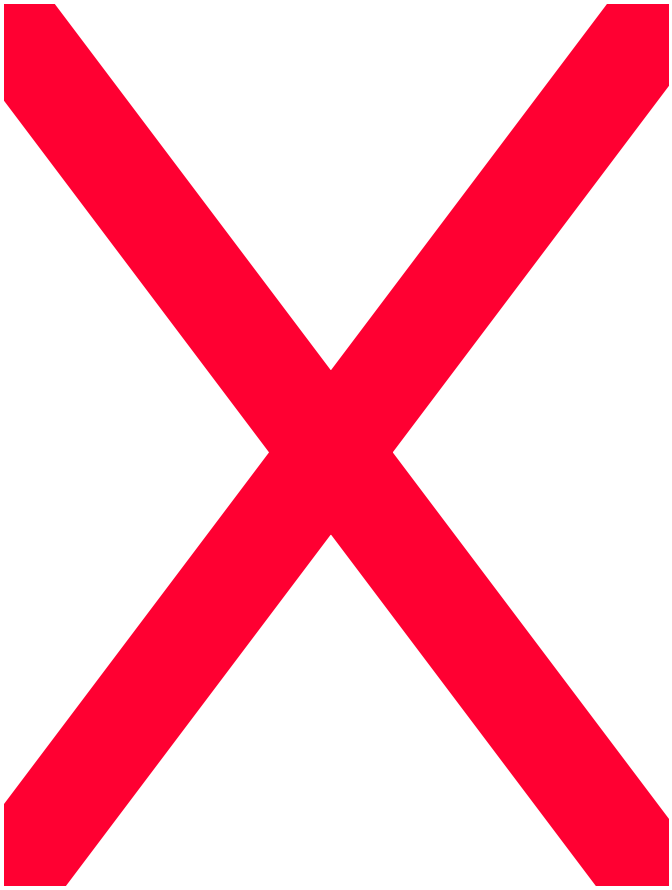
- **Biomedicine:** **Billions/yr**
- **Human Genome:** **$1 - 2 B so far**
- **Inform. tech:** **> $1.5 B/yr**
- **Materials res:** **> $1.5 B/yr**
- **Adv Photon Src:** **$1 B const**
- **Spall. Neut Src:** **$1.5 B const**
- **Astr/Astrophys:** **> $2B/yr**
- **Hubble Space Tel:** **$2 B**
- **Chandra X-ray Tel:** **$1.5 B**
- **Next Gen Space Tel:** **>$1.0 B**
- **Space Station:** **$100 B ??**

US Particle and Nuclear Physics: ~ $1.2 B/yr

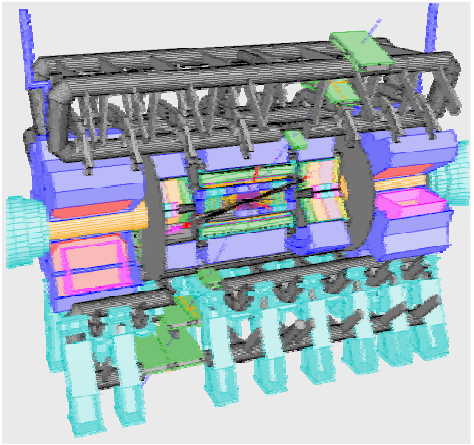
The Changing Emphasis of Federal Academic R&D

Major Field Shares of Agency Obligations Reported to NSF Surveys





The Grid Physics Network



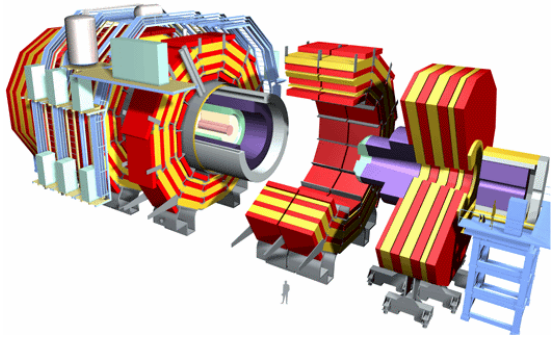
LHC
ATLAS Detector

GriPhyN

Data Intensive Science

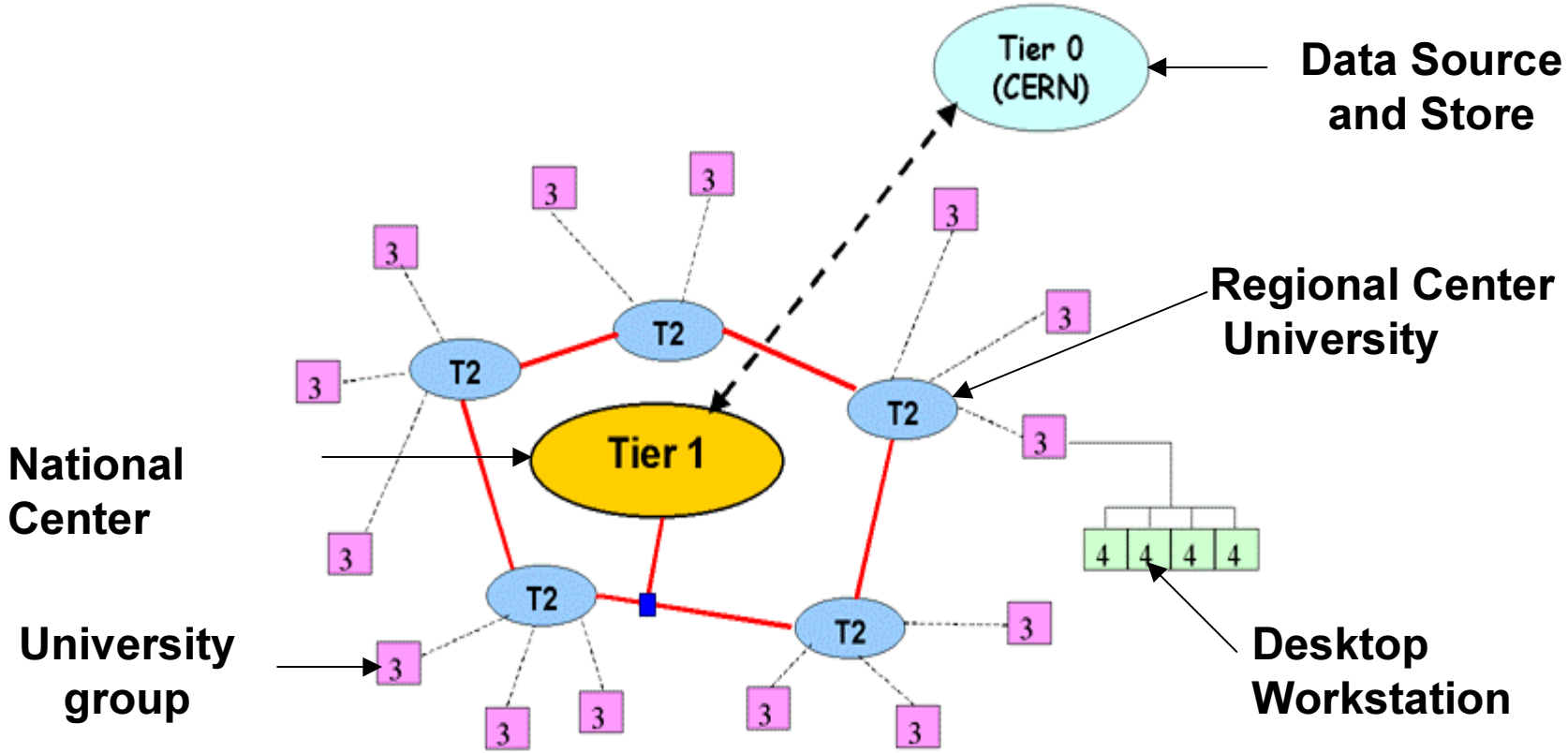
Sloan Digital Sky Survey

LIGO



LHC
CMS Detector

A Hierarchical Computational Data Grid for Large Experiments



FY 2000: R&D award to produce Grid middleware - $11.9 M

FY 2001: Prototype Tier 2 centers & testbeds - $10.0 M